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2nd Scientific Conference on the Use of Offshore Wind Energy by the Federal Ministry for the Environment 20. and 21. February 2007 in Berlin

Conference Proceedings

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Introduction

Leena Morkel – TU Berlin
Translation: Leena Morkel, Alexandra Toland – TU Berlin

The German government is striving to significantly increase the amount of renewable energy in Germany's total energy supply. On the one hand renewable energies shall contribute to Germany's goals of climate protection. On the other hand the use of renewable energies can gradually reduce the dependency on expensive and limited fossil fuel resources. Of all renewable energies, wind energy has the biggest potential for intermediate-term development. The use of wind energy is increasing at an exponential rate worldwide.

Germany is leading the way in the use of wind energy, currently satisfying about five percent of its power consumption demands with wind energy. The construction of several offshore wind farms in 2006 has generated a greater dynamic for the use of offshore wind energy throughout Europe. Germany has made a great contribution towards this recent trend. The first 5-Megawatt wind energy turbines that can be used offshore have been developed in Germany. The German offshore wind energy test site located in the North Sea (offshore wind farm Alpha Ventus) will start operations in 2008. It will be used for the first testing of the operation of twelve 5-Megawatt wind energy plants in deep waters and at a great distance from the coast. Moreover, permits for 18 further pilot projects have been granted and three especially suitable areas for the use of wind energy have been designated in areas of the North and Baltic Seas.

Through the promotion of research and development projects, the Federal Ministry for the Environment contributes to the expansion of wind energy. Important objectives include the gradual reduction of costs for the production of wind power, and sustaining Germany's competitive position in the wind industry. Furthermore, the expansion of offshore wind energy is to be carried out in a manner compatible to nature and the environment. The accompanying ecological research analyses the influences of offshore wind farms on the marine environment in interdisciplinary and cross-border projects. It promotes the development of adequate strategies for the avoidance or mitigation of environmental impacts. With the construction and operation of research platforms in the North and Baltic Seas, a solid pool of information will be created for the future expansion of offshore wind energy as well as the design of power plants and foundations suitable for use in marine environments.

At the „1st Scientific Conference on the Use of Offshore Wind Energy" in 2004, the Federal Ministry for the Environment presented results of federally endorsed projects. The continuation in this series of conferences, "the 2nd Scientific Conference on the Use of Offshore Wind Energy by the Federal Ministry for the Environment", took place on February 20th and 21st 2007. The Technical University Berlin was commissioned by the Federal Ministry for the Environment together with Projektträger Jülich to organize and administrate the conference.

Scientists presented their latest project results. Natural conditions of marine ecosystems were discussed as they relate to wind energy use. Furthermore, new technical methods were demonstrated to identify environmental impacts. New ideas were presented on how to implement the use of offshore wind energy in an environmentally compatible manner. The presentations showed an enormous progress of relevant research about the use of offshore wind energy.

The conference presented opportunities to develop new research goals within the scope of the wind energy test site Alpha Ventus. Furthermore, the conference showed developments on the use of offshore wind energy in several neighbouring countries.

An audience of more than 200 researchers and representatives of political, economical, governmental and non-governmental organizations from 13 countries participated in the conference.

The conference proceedings of the „2nd Scientific Conference on the Use of Offshore Wind Energy by the Federal Ministry for the Environment” comprise summaries and conclusions of the event’s presentations.

The German offshore-foundation and the offshore wind energy test site

Summary of the speech by Jens Eckhoff – German Offshore-Foundation
Summarized by Leena Morkel – TU Berlin
Translation by Leena Morkel, Alexandra Toland – TU Berlin

In February 2007 a brochure about offshore wind power deployment in Germany was published by the Offshore-Foundation and by the Federal Ministry for the Environment (BMU).

Altogether a great potential for the use of offshore wind energy exists. According to an EU-study, 2x of the energy requirement of the EU can be covered by the use of offshore wind energy. Wind speeds at sea are about 70 – 100% higher and more constant than onshore. New developments of wind energy turbines with a capacity of 5 MW and more can use the potential of wind energy at sea. These prototypes are already available, are partly constructed already and actually tested for practical use.

The European dimension of offshore wind energy is strengthened by a prognosis of the European Wind Energy Association. It assumes that about 13% of the European power consumption could come from offshore wind energy by the year 2030. Therefore 150,000 MW must be installed in Europe.

The political hour of birth of offshore wind energy in Germany was the day in March 2000, when the Renewable Energy Sources Act became effective. In this law a special feed-in tariff for offshore wind farms in coastal marine areas and in the Exclusive Economic Zone (EEZ) was regulated for the first time. This introduced several challenges. Among other things, questions about construction and energy feed-in had to be solved. At that time medium sized companies were involved in the planning of offshore wind energy turbines, but for the installation of offshore wind farms large investments were necessary.

At the conclusion of the 4^{th} National Maritime Conference in January 2005 in Bremen, it was decided that a test site for the use of offshore wind energy in Germany would be required. The final declaration of the conference called upon the German federal government to become active in this area. The declaration gave a sense of courage to all those involved and raised the tempo for off shore wind energy use deployment in Germany. Because of the activities of the BMU in 2005, the offshore foundation was established. The foundation especially pursues the following four main topics:

- Technological research, development and innovation in the field of offshore wind energy with consideration of energy transport means to the consumer.
- Ecological research about the effects of the construction, operation and removal of offshore wind energy turbines and their grid connections on the marine environment, as well as research on the ecological optimisation of wind energy turbines.
- Research about the suitability and effectiveness of governmental instruments for the support of offshore wind energy with regard to environmental and climate protection.
- Support for the exchange of knowledge about offshore wind energy between scientific, economic and other public and private organizations.

In 2005 the offshore foundation secured its rights on the test site with the help of the BMU. In 2006 the foundation, together with the energy suppliers, RWE, EON and Vattenfall, and the producers of wind energy turbines, Repower and Multibrid, agreed on a corporate declaration concerning the central points of the realization of the test site. The Federal Environmental Minister furthermore announced that an estimated investment sum for the 12 turbines would be around 175,000,000 €.

Within regard to implementation, problems and questions must also be solved. Political instruments have to be reviewed on their effectiveness. For example, all wind energy turbines that will be built by 2011, will be exempted from the grid connection. These basic conditions have to be checked again, as the time limit of 2011 might be rescheduled due to global market trends. Also the feed-in tariff must be discussed again. A study of different countries, e.g. Great Britain and France, with their diverse developments of feed-in tariff is necessary. Which models are used there? It is important to follow developments abroad and to draw conclusions and consequences based on the different experiences about the feed-in tariff. After some time the feed-in tariff must eventually be readjusted.

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Research and development at the offshore test site – focus of the Federal Environment Ministry's research support in the field of wind energy

Ralf Christmann – Federal Ministry for the Environment, Nature Conservation and Nuclear Safety,
Division Research and Development in the Field of Renewable Energies

Abstract

Although Germany is a leader in wind power technology, it runs the risk of missing the boat as far as the international development in the offshore sector is concerned. The need for ongoing research is therefore crucial. As a lighthouse project and initial step for offshore wind development in Germany the realisation of an offshore test site in the North Sea was promoted and will be supported by the Federal Environment Ministry (BMU). During the next five years the BMU will provide about € 50 million for research activities at the test site, which will consist of 12 wind turbines of the 5 MW class. Research projects will focus on the testing, operation and development of offshore wind technology; accompanying ecological research will be carried out under real conditions.

Germany is the world leader in the development of wind turbines. Three systems from German manufacturers with a capacity of 5 MW and more currently form the flagship of this development. One of the most powerful turbines worldwide is the Repower 5M. The development of the other two - Enercon E 112 and the Multibrid M 5000 - received research funding from the Federal Environment Ministry (BMU).

Despite this enormous technological lead, Germany runs the risk of missing the boat as far as international development in the offshore sector is concerned. Turbines are already generating electricity off the coasts of Sweden, Denmark and Great Britain. Although German manufacturers are represented at these sites, they do not yet have turbines in operation in Germany. Other countries have already moved a step further as it has been possible to erect test and pilot turbines at lower water depths and closer to the coast. In European waters, especially off the coasts of Denmark, Sweden and Great Britain, more than 600 MW have already been installed. In contrast, in Germany only two turbines were in operation close to the coast since at beginning of 2007. There is a danger that although Germany is the technological leader, it cannot make the most of this lead. This is why erecting offshore turbines for demonstration is the top priority for research support.

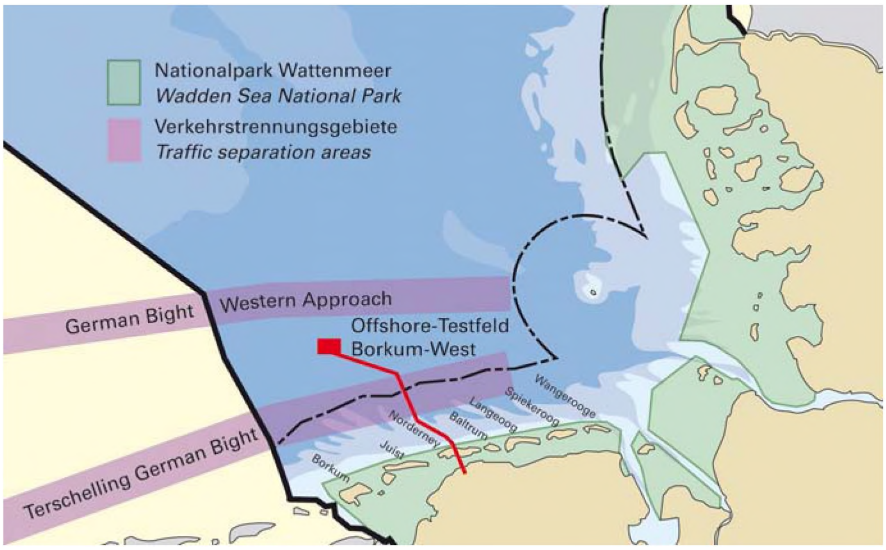
Furthermore, the greatest potential for the further expansion of wind energy in Germany lies offshore. According to conservative estimates, around 7,000 to 10,000 MW offshore capacity could be installed by the end of 2020. The BMU's roadmap for wind energy research indicates a capacity of up to 15,000 MW. The German Government is also committed to its long-term target of up to 25,000 MW by 2030.

Germany is falling behind in the offshore sector because of the difficult natural preconditions at the 18 German wind farms that have already been licensed in the North and Baltic Seas. There is a lack of practical experience in water depths of up to 40m and at distances of up to 200km from the coast. The projects that have already been carried out in other European countries cannot be implemented in the same way in Germany.

This means that in addition to the already high demands on wind turbine technology due to the rough marine environment, there are also considerable challenges facing wind farm project planners and potential operators regarding foundation, grid connection and logistics. These challenges bring with them a significant risk which, in particular when the issue of financing is addressed, is perceived as an investment risk, hampering the setting up of offshore wind farms.

Pilot project "offshore test site" in the North Sea

In order to gain the experience needed for the expansion of offshore wind energy in Germany, the first offshore pilot project is currently being realised. In 2005 the BMU created the prerequisite for setting up a test site by providing 5 million euro for the purchase of the rights for a licensed wind farm. At the end of 2006 the rights were leased to a consortium of the energy utilities EWE, E.ON and Vattenfall. The consortium gave a contractual undertaking to set up a test site of 12 wind turbines of the 5 MW class at this site in 2008. The offshore test site is located in the North Sea beyond the 12 nautical-mile zone, approx. 45 km north of the island of Borkum. In fact the test site is the former fully licensed wind farm Borkum-West. The research platform FINO 1 is in the direct vicinity. The water depth at the site is 28 to 30m, the necessary grid connection is made via 66km at sea with additional crossing of the island of Norderney and further cable routing of 4km over land to the next feed-in point at the coast.



The offshore test site is the spark that has been missing from the development of offshore wind energy use in Germany thus far. This project will for the first time provide an opportunity to test 5 MW turbines under real conditions at sea and to further develop this technology. The BMU will support this and - in addition to the investment costs to be borne by the operators - will provide 50 million euro for research and development projects at the test site over a period of 5 years. This project thus becomes a "lighthouse project" for the BMU's research support in the wind energy sector.

The Federal Environment Ministry's test site research programme

The Federal Environment Ministry's comprehensive test site research programme aims both at operators and manufacturers of turbines and at other interested parties, e.g. universities, research institutes and the maritime industry. The goal of this programme is to help offshore wind energy use in Germany achieve a breakthrough by demonstrating the offshore suitability of large multi-MW turbines and enabling turbines to be further developed on the basis of experience gained at the test site. The test site will also contribute to reducing the costs of expanding offshore wind energy use (turbine construction, foundation, insurance, etc). This will also benefit other offshore projects. The findings of the supported projects will be made available to a broad public unless the commercial and industrial confidentiality of the stakeholders involved is affected.

The Federal Environment Ministry's research and development programme for the test site comprises the following focal points:

- foundations and tower structures
- testing components under offshore conditions
- measuring and monitoring yields and operating experience
- recording and simulating wind farms effects (e.g. to determine the influence of wake currents on the load pattern and the lifetime of turbines)
- elaborating logistic concepts and developing appropriate technology
- accompanying tests during the construction, operation and maintenance of turbines
- further development of farm control technology
- integrating electricity generated into the grid
- output curves, turbine dynamics and stresses on offshore wind turbines
- research on possible impacts of the test site on nature and the environment (accompanying ecological research) under real conditions.

A continuous coordination and information process with the wind energy industry, the scientific community and the operator consortium has been ongoing since June 2006 concerning the goals, procedures and framework conditions for research at the test site.

In view of the high level of coordination required among all stakeholders, this process was not easy. Ultimately, it was a question of reconciling the wishes and proposals of researchers with the demands of the operator consortium and turbine manufacturers involved - not only regarding use of the turbines, but also use of the data before, during and after projects. In addition to confidentiality concerns of the manufacturers and operators, issues such as warranties, logistics and safety also have to be clarified. It was therefore important to agree on the rules concerning access to the turbines, for example, so that researchers can install and operate measuring equipment.

There are now numerous outlines and applications for R&D projects that are selected in accordance with specific criteria in the framework of the standard procedures for research funding. Priority is given to projects of an urgent nature e.g. with influence on the planning and construction of wind turbines and the systems for grid connection. In parallel to the review and selection of research applications there is a continuous coordination with operators and manufacturers in order to ensure that ongoing processes for implementing the "offshore test site" project are not jeopardised.

The issues addressed in the submitted R&D projects range from planning and coordinating numerous R&D activities to technological developments, data management and measuring and monitoring results. In addition to concrete projects on accompanying ecological research, cross-cutting measures such as evaluating test results for offshore wind farms using the example of the test site were also submitted. This aspect is important since the expansion of offshore wind energy in Germany has to be nature-friendly and environmentally sound on the one hand but on the other hand must not lead to incalculable costs and risks.

To summarise it can be concluded that this programme is the most comprehensive research programme (including technical and ecological monitoring) to date in the field of offshore wind energy use.

The lighthouse project "offshore test site", as a concerted action by industry, the scientific community and policymakers, is groundbreaking for the development of offshore wind energy in Germany. This pilot project aims to demonstrate the suitability of German turbine technology for the high seas and to advance further developments in the field of offshore wind energy use - from the foundation to the turbine, from construction to maintenance logistics and from grid connection to the grid-stabilising operation of turbines. And this is taking place with verifiable consideration of nature and environmental concerns.

The role of the research platforms FINO 1 - 3 in the technical and ecological support research on offshore wind energy use

Antje Finger – Federal Ministry for the Environment, Nature Conservation and Nuclear Safety

Abstract

Electricity from offshore wind energy will in future make an important contribution to reaching the targets for increasing the use of renewable energies and protecting the climate. The construction of three research platforms was decided on in order to gather the findings needed for the expansion of offshore wind energy in Germany. The purpose of these platform projects is to improve knowledge above all about the meteorological, hydrological and ecological conditions at sea. These results will provide important findings that are needed for the assessment of technologies and their impact on the environment. The data collected will serve as a basis for example for calculating possible energy yields and drawing conclusions regarding the optimal technical design of turbines. Additionally, the possible impacts of offshore wind turbines on marine nature and environment will also be studied.

In accordance with the Federal Government's offshore strategy, the first research platform - FINO 1 - was erected in summer 2003 in the North Sea approx. 45km north of Borkum. It has supplied a continuous flow of data ever since. A second research platform - FINO 2 - was erected in the Baltic Sea in June 2007. The third platform - FINO 3 - is due to start operation in the North Sea at the beginning of 2008.

Background

In the medium term the use of offshore wind energy offers the greatest potential among renewable energies for reaching the expansion targets for the share of renewable energies in electricity supply in Germany. Worldwide there is no experience regarding the erection of offshore wind parks located in deep waters and large distances from the coast. In accordance with the "strategy of the German Government on offshore wind energy at sea" (German Government 2002), a total of three research platforms (**F**orschungsplattformen **i**n **N**ord- und **O**stsee - FINO) are therefore to be set up in preparation for offshore wind energy use. There are data gaps or only little data on many aspects, e.g.:

- What exactly are the wind and weather conditions in the offshore sector?
- What stresses are placed on wind turbines?
- What form does bird migration take and can this come into conflict with wind turbines?
- etc.

The aim is to find answers to these and many other questions by means of tests at the research platforms. A basis will be created for a broad circle of users - e.g. turbine manufacturers, planners, operators, construction companies, licensing authorities and nature conservation stakeholders - for assessing the opportunities and impacts of offshore wind energy. The goal is to reduce existing risks and accelerate the expansion of the planned offshore wind farms. Detailed measurements and tests will be carried out at the platforms and during their construction that take into account technical, metrological, hydrological and biological aspects. As a result of these long-time data series it will be possible to achieve greater prediction certainty.

Manufacturers and investors will have greater certainty with regard to turbine construction and assessing economic efficiency. The data collected will provide a valuable basis for optimising turbine and foundation construction and for the design, erection and operation of offshore wind turbines.

One focal point will be identifying possible impacts of offshore wind turbines on the marine environment and the development of options for avoiding and reducing negative impacts. For example, in the framework of ecological support research, aspects such as bird migration, the risk of bird collisions, the settlement of benthic organisms and possible attractant effects on fish will be studied at the research platforms. Measurements will be taken during the piling operations for the platform foundations on noise impacts and measures to reduce construction-related noise will be tested. The main aim of these measures is to protect marine mammals.

The results of the platform research are very significant from a technical and ecological perspective for assessing offshore wind energy and are an important contribution to improving the data basis in the offshore sector.

Research platform FINO 1

The research platform FINO 1 has been in operation since September 2003 and has since been providing a continuous supply of data.

Figure 1: Research platform FINO 1 in the North Sea (Copyright: BMU / CHRISTOPH EDELHOFF)

FINO 1 is locating in the North Sea approximately 45km north of the island of Borkum. The water depth at the platform's location is 28m. The platform can be reached in 3-4 hours by boat or only 35 minutes by helicopter.

The research platform is located in the central cluster of the "Nördlich Borkum" preferred area. The site of the planned offshore test field is located in the direct vicinity of FINO 1. From 2008 the construction of 12 turbines of the 5 MW category is planned only approx. 400m east of the platform.

Project data

Germanischer Lloyd WindEnergie GmbH was commissioned with the project coordination for the construction and operation of FINO 1.

The foundation of the platform has a jacket structure that is anchored in the seabed by 4 piles (diameter each 1.5m, length 38m).

The platform deck (16m x 16m) is located 20m above sea level (chart datum). The five containers hold measuring equipment, computers, offices, emergency accommodation and the diesel generator. A wind measuring mast has been installed on the platform deck with a height of 101m (chart datum). The platform is also equipped with an offshore crane and a small crane installation for taking soil samples.

Measurement and research programme

A number of measurements and tests, listed below, are being carried out at the research platform in order to identify the environmental conditions (meteorology, hydrology, etc) and the impacts on nature and the environment. The measurements at FINO 1 are automatic and can in part be controlled from on land. The data is relayed onshore via directional radio and evaluated by the participating scientific institutions. Scientists and maintenance workers only travel to FINO 1 once or twice a month, by helicopter.

The FINO 1 website (http://www.fino-offshore.de) shows pictures from the live webcams and provides daily and weekly data on certain parameters. Additionally, quality-controlled data from the fields of meteorology, oceanography and structural measurements are available from the FINO database (http://fino.bsh.de). The data collected from FINO 2 and FINO 3 will also be made available here in future.

Meteorological measurements

With the aid of sensors, a range of meteorological parameters are measured at FINO 1, for example:

- wind speed and direction, turbulence
- rain
- lightning
- air temperature, humidity, air pressure,
- global radiation, UV-A, visibility.

These long-time measurements can, for example, facilitate the calculation of possible energy yields and the drawing of conclusions regarding the optimal technical design of wind turbines. The measurements show that the average wind speed at a height of 100m is around 10m/s. Wind speed is greater than 4m/s for around 8000 hours per year, which means wind turbines can produce electricity for more than 90% of the year. The predictions on the potential energy yield calculated on the basis of the wind data are around twice as high as those for a good onshore location.

The technical measurements and the processing of the data are carried out by the German Wind Energy Institute (DEWI) in cooperation with the Federal Maritime and Hydrographic Agency (BSH).

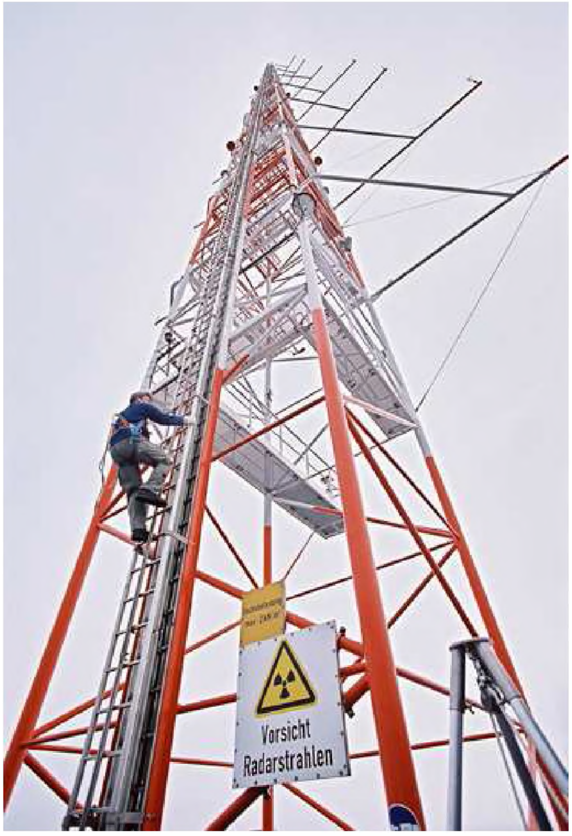


Figure 2: FINO 1 wind measuring mast (Copyright: BMU / CHRISTOPH EDELHOFF)

Oceanographic measurements

The BSH is carrying out a range of measurements to identify various oceanographic parameters, for example:

- sea conditions (wave height, frequency and direction)
- speed and direction of current, water level
- water stratification, water temperature, salinity, oxygen content.

The measurements provide valuable input data for calculating the construction stress and for optimising the foundation design of offshore wind turbines.

Ecological measurements

<u>Processes in the close vicinity</u>

The Alfred-Wegener Institute in Bremerhaven (AWI) is investigating the populating of the underwater structure of the platform by marine organisms (benthos) in the framework of the research projects BeoFINO and BeoFINO II. Furthermore, changes in the sediment composition in the close vicinity of the platform and resulting changes to the benthic community and their scope are also recorded. The documentation of attractant effects on the fish fauna is also part of the research.

Measurements taken at the platform and in its vicinity will serve as a foundation for modelling the spatial effects of offshore wind farms.

In the framework of this project, the following testing methods are among those applied:

- sampling with van Veen grabs
- samples of benthos collected by divers
- steel plates suspended underwater
- mobile underwater camera
- plankton sampling with nose net und plankton pump
- fish echo sounder.

Figure 3: Taking sediment samples from the seabed (Copyright: BMU / CHRISTOPH EDELHOFF)

<u>Recording bird migration</u>

The Institute for Bird Research ‘Vogelwarte Helgoland’ is carrying out comprehensive tests on bird migration over the German North Sea as part of the research projects BeoFINO and FinoBird. A number of recording methods and equipment have been developed and tested for this purpose:

- vertical and horizontal radar
- thermal imaging and video camera systems
- audio system for recording bird calls
- bat detector system.

The long-time tests at FINO 1 supply valuable information on spatial and temporal distribution of bird migration over the North Sea with a view to potential locations for offshore wind farms. By means of combined technologies is it possible to record, inter alia, the species spectrum, flight height, direction and times and the reaction of animals to offshore constructions. With the help of these tests, knowledge about bird migration over sea can be significantly improved and initial estimates can be made on possible impacts of offshore wind farms.

Further tests

In addition to the tests described above, a range of other research projects are being carried out at FINO 1. These include:

- measuring noise emissions and noise propagation during the ramming of the foundation piling (Curt Risch Institute Uni Hannover, German Wind Energy Institute - DEWI, Institute for Technical and Applied Physics - itap)
- testing stresses on the foundation structure /stress measurements (DEWI)
- recording movement of ships and AIS (automatic identification system) data in the sea area around FINO 1 (Northern and North-western Waterways and Shipping Directorates)
- testing a LiDAR (“light detection and ranging”) wind measuring system (WINDTEST)
- testing physical soil parameters (project by the German Research Foundation DFG).

In future FINO 1 could also serve as a basis for constructional research and research during operation at the offshore test field.

Research platform FINO 2

In June 2007 the research platform FINO 2 was erected in the Baltic Sea. Following conclusion of the installation work and the function tests, the measuring operation is due to start shortly. The platform is located approx. 40km north of Rügen at a water depth of approx. 20m. FINO 2 is thus in the northern area of the “Kriegers Flak” preferred area for wind turbines and the planned offshore wind farm of the same name.

Project data

The Federal Environment Ministry is providing 3.5 million euro for the construction of FINO 2. The Federal State of Mecklenburg-Western Pomerania is also contributing 1.3 million euro. The Warnemünde Navigation Institute (Schifffahrtsinstitut) is managing the project.

The monopile foundation of the platform was erected in October 2006. A 50.5m-long, 270-tonne steel rod was driven into the seabed to a depth of around 25m.

The platform is equipped with a wind measuring mast and containers for measuring technologies.

Measuring and research programme

Similar to FINO 1, meteorological long-time measurements, particularly on different wind and weather parameters, will be carried out at the research platform in the Baltic Sea.

Additionally, data on shipping movements will be recorded via AIS (automatic identification system) and a system will be applied for active transport safety on the platform.

The ecological measuring programme comprises tests on the population of hard substrates with the aid of steel plates suspended underwater. It also aims to record bird migration and the risk of bird strike with the aid of radar and camera systems. Tests will also be carried out on a small scale regarding fish and marine mammals.

During the piling for the platform foundation, successful tests on noise reduction were carried out by the Institute for Structural Analysis (ISD) at the University of Hannover and the Institute for Technical and Applied Physics (itap). Measurements were also taken regarding the propagation of underwater noise.

Research platform FINO 3

A third platform, FINO 3, is due to be erected at the beginning of 2008 approx. 80km west of Sylt at a water depth of 23m. The planned location is close to the planned offshore wind farms DanTysk, Nördlicher Grund and Sandbank 24.

Project data

The Federal Environment Ministry is providing 5.2 million euro for the FINO 3 project. The Land of Schleswig-Holstein is contributing a further 6.4 million euro. The Research and Development Centre GmbH at the Kiel University of Applied Science (FH Kiel) has taken on the project management and coordination.

A monopile is planned as the foundation for the platform. The platform deck will be installed around 22m above the water surface. In addition to two containers for energy supply and the measuring technologies, an 85m-high wind measuring mast will be erected on the deck. This will be equipped with a lightning rod. The entire construction will therefore reach a height of 120m above sea level.

The platform will be equipped with a helicopter deck to ensure good accessibility.

Measuring and research programme

In addition to the construction and erection of the platform, the FINO 3 project also comprises a physical-technical test programme. The following research projects are currently under preparation:

- Measurement and analysis of high-frequency (<10 kHz) turbulence parts in the offshore wind for optimisation of aerodynamic sheet profiles (Kiel University of Applied Science)
- Measurement of flash frequencies and flash electricity parameters on the sea (Kiel University of Applied Science)
- Technology for ground pre and post investigations of offshore buildings with 3D seismic reflection, shear and compression wave tomography, to quantify the danger potential as a result of structural changes in the ground (Christian-Albrechts University in Kiel)
- Geotechnical in-situ measurements and supplementary pilot projects for ultimate state examinations for the foundation of offshore wind energy plants (Technical Institute (TU) Carolo Wilhelmina in Braunschweig)
- Swell and breaker survey by Doppler measurement (FINO3 / SEEDOM) to investigate the spatiotemporal changeability in the swell field of offshore buildings (GKSS Research Centre Geesthacht GmbH)

- Meteorological measurements at the measuring pole of the offshore research platform FINO3: supply and installation of the measuring system, operation, supervision, interpretation of the measurements and maintenance (WINDTEST Kaiser-Wilhelm-Koog GmbH)
- Oceanographic measurements at the offshore research platform FINO3: installation and operation of the measuring system, survey, archiving and valuation of the oceanographic data (Federal Maritime and Hydrographic Agency (BSH).

In the framework of the accompanying ecological research on offshore wind energy deployment, further tests are also prescribed on bird migration over the North Sea. The testing of additional noise reduction measures and measurements on the propagation of underwater noise is also planned during the piling for the foundation.

Further information

More detailed information on the research platforms and contact data for the relevant partners are available on the following websites:

http://www.fino-offshore.de

http://www.bine.info/pdf/publikation/projekt0905internetx.pdf

http://www.fino2.de

http://www.fino3.de

Focal points and developments in wind energy research of the Federal Ministry for the Environment since 2001

Joachim Kutscher – Projektträger Jülich (PtJ)
Translation: Alexandra Toland, Leena Morkel – TU Berlin

Abstract

This article gives a short review on the wind energy research supported by the German Federal Government since 2001. The basis for this governmental support is the 5th Energy Research Programme of the Federal Government and under this programme the publication of funding schemes for wind energy research of November 2004 and of September 2006. The overall objectives of funding are directed towards a still improved and competitive position of wind energy in the national energy market as a renewable source with high potential. Further improvement of generator technologies, grid characteristics and production processes shall enable the wind industry to successfully participate in the rapidly growing world market and expand the wind energy deployment as a climate compatible technology worldwide. A focus in research is given to new offshore specific aspects especially for offshore wind energy deployment far from the shore, as it will be the case in Germany. The article gives some information about the development of the research budget and highlights some important research projects without being able to consider the complete spectrum of research of the last years.

General conditions of funding

The endowment possibilities for research and development programmes by individual national governments are regulated in the European Union (EU) by the EU-Commission in the “Regulation on State Aid for Research and Development and Innovation”. In order to ensure that state aid does not distort market competition, particular cases are outlined in which national assistance is permissible. The community framework sets out to eradicate clearly defined forms of market failure, which hinder the ability of research and development from operating at an optimum level. The long-term goal is finally the enhancement of economic efficiency. The community framework also describes the conditions for government subsidies, funding instruments and limitations of funding as well as incentives for special research structures and target groups.

The 5th Energy Research Programme of the Federal Government elucidates the goals of national funding for research and development, relevant for all kinds of energy production and issues of rational energy deployment. In consideration of the community framework described above, the EU Commission approved (notified) the 5th Energy Research Programme of the German Federal Government in November 2005. In doing so, the EU Commission specified which funding mechanisms and maximum funding valuations were appropriate for this national programme.

The focal points of the current wind energy research were outlined in the funding announcements of the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) in November 2004 (expired) and in September 2006. Endowment goals include e.g.:

- cost reductions,
- yield increase and
- increased availability of wind energy facilities,

as well as thematically specific goals such as:

- the integration of large scale wind energy into the grid,
- offshore-suitability of multi-megawatt turbines,
- optimisation of offshore foundations,
- and the technical development and logistic concepts for offshore assembly procedures

were discussed by the BMU and the Projektträger Jülich (PtJ) in strategic consultation with experts from the wind industry, prominent research establishments and from industry and environment organizations.

Development of the utilisation of government subsidies

After considerable federal funding of wind energy research at the beginning of the eighties, with up to 22 million Euros of research support in 1981 alone, a steady decrease in government funding to wind energy research followed in the years after. This decrease lasted until the end of the nineties, with approximately 2 million Euros of funding in the year 2000. The high availability of funds at the beginning of the eighties was above all connected with the model project GROWIAN, a 3 MW wind energy turbine that was erected by a consortium of companies for testing purposes. The predicted electrical capacity of the GROWIAN amounted to 3 MW, while the rotor had a diameter of 100.4m. Due to many unsolved questions concerning material structure at that time, the plant however, hardly operated in its test phase. With the try of an output of sixty times higher than that of the state of the art at the time, the project was doomed a failure. On the other hand, important conclusions could be drawn, allowing German equipment manufacturers to successfully integrate into the MW-class wind energy market about ten years later.

The political disappointment surrounding this project was, among other things, a reason for the strong decrease in funding for technological development of wind power utilization at the beginning of the nineties. The 100 and 250 MW-wind energy-programme of the Federal Government had nevertheless a strong impact on the development of wind energy. Operators were subsequently subsidized in their acquisition of wind energy turbines. In response, the operators were obliged to make operational data available for scientific measuring and evaluation as part of the Scientific Measure- and Evaluation Programme (WMEP), which was carried out by the Institute for Solar Energy Supply Technology (Institut für Solare Energieversorgungstechnik e.V. Kassel, ISET).

After considerable advancements in the development of wind energy on land, increasing attention turned from 2000 onward again to the possibilities of offshore wind energy utilisation. Thanks to available revenues from the sale of UMTS mobile phone licenses, the Future Investment Programme of the Federal Government (ZIP) was able to allocate 15 million Euros for the construction of offshore research platforms at short notice, as well as approximately 4 million Euros for accompanying ecological research for the evaluation of the environmental compatibility of offshore wind energy utilization. Fig. 1 shows the progression of funding for wind energy research, allocated annually by the BMU over the last ten years.

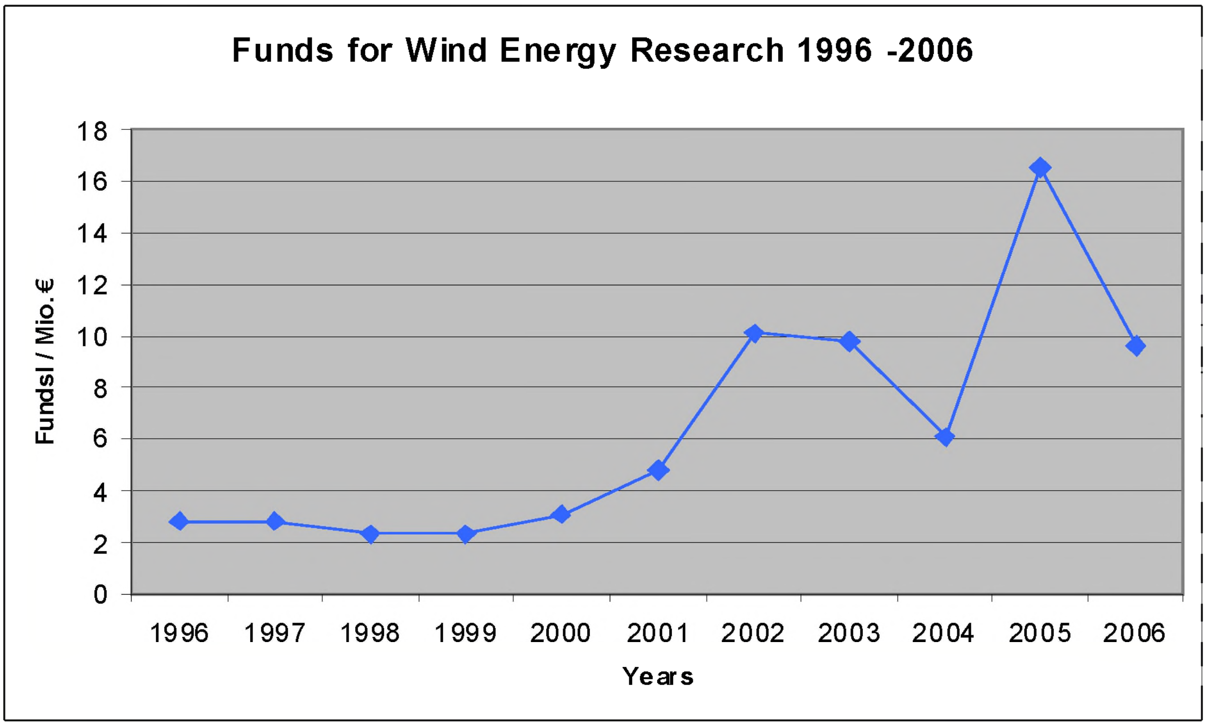


Figure 1: Progression of government funding for wind energy research since 1996

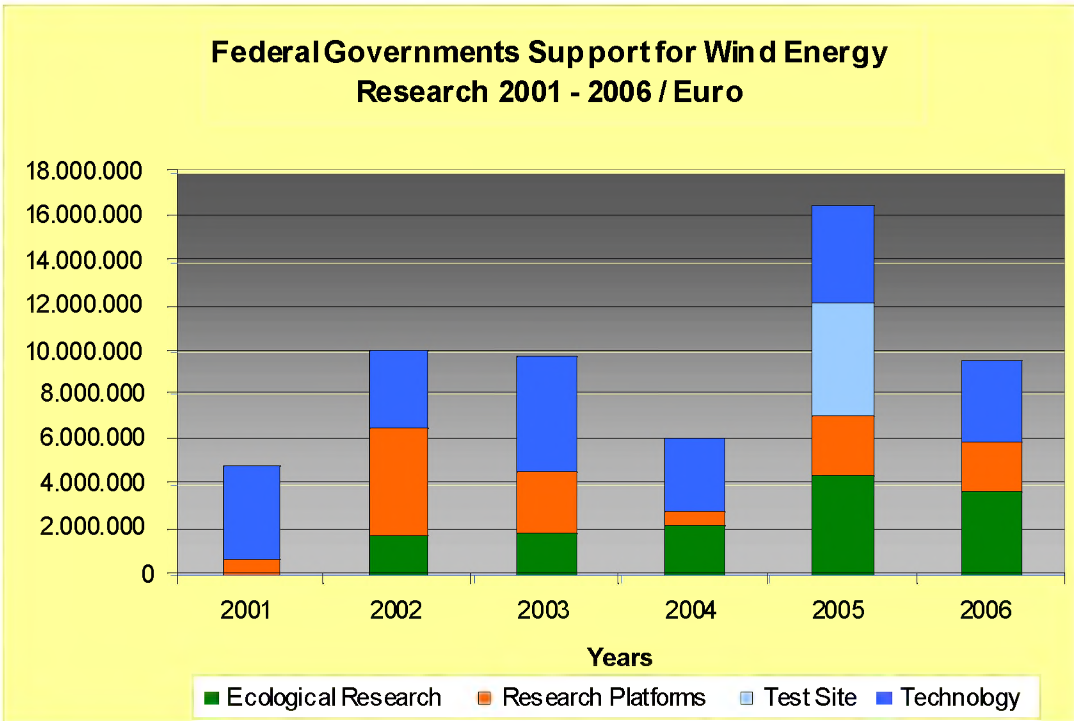


Figure 2: Focal points of annual funding

The allocation of funding since 2001, illustrated in fig. 2, shows the different focal points.

The proportion of technological to ecological research was held in a relative balance over the last few years. Based on the background of technical challenges surrounding upcoming offshore development, initial experiences with technical difficulties stemming from other European countries with offshore wind farms, the general grid-technological requirements of a constantly growing wind energy supply, and due to the fundamental emphasis of the 5th Energy Research Programme, this balance is predicted to shift in favour of technological research over the next few years. This trend is already reflected in the distribution of funds in 2006, with a total of 16 million Euros for 28 new granted projects (fig. 3).

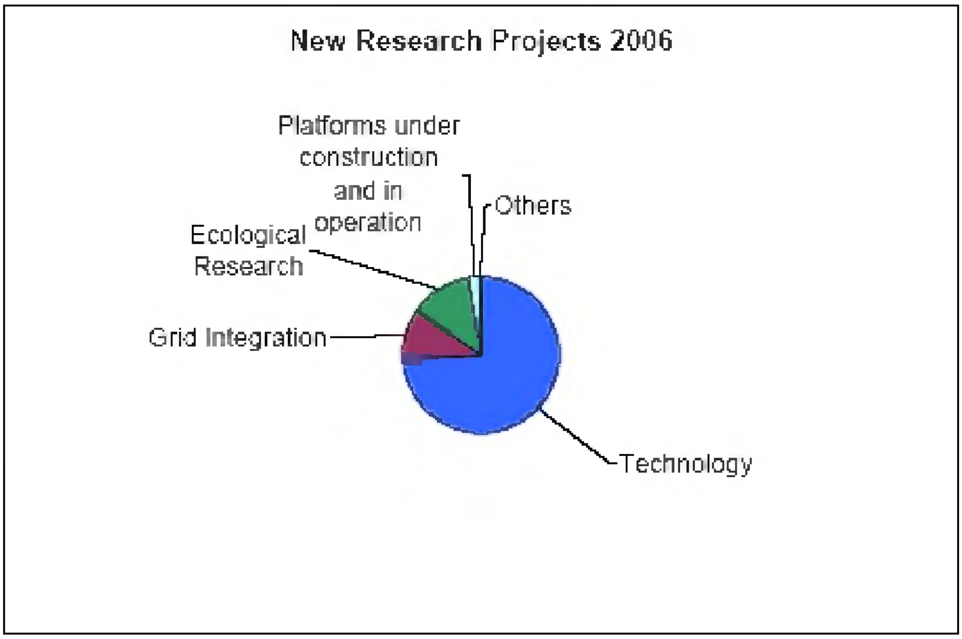


Figure 3: Distribution of funds for research projects granted in 2006, amounting to a total allocation of 16 million Euros. Included in the sum is the funding for subsequent years, where normal project duration generally lasts three-years.

Since the BMU became responsible for research in the area of renewable energies in January 2003, a substantial increase in the Federal Government's commitment to wind energy research is to be registered, and is to continue over the years to come.

Altogether 99 new research projects in the area of wind energy have been backed by government funding since 2001, with a total of 36 projects focused on accompanying ecological research for wind energy utilization.

Research highlights

It is not possible here to name all the large scale projects and research networks, which have contributed to the fundamental advancement and application-oriented realizations of many aspects of wind energy deployment. Only several funded projects can therefore be addressed here. Independent of funding amounts, these exemplarily described projects are of importance for the development of wind energy in Germany and beyond.

Included in the funding are the two first worldwide wind turbines of the 5 MW class:

- The prototype Enercon E112, with 4.5 MW capacity was erected in 2002 near Magdeburg. In the meantime, 9 further plants were built, of which three further turbines of 6 MW capacity.

- The prototype Multibrid M5000, likewise funded by the BMU, was erected in December 2004, in Bremerhaven. In 2006, the Multibrid Development Company Ltd. successfully mounted a second turbine onshore but on an offshore test foundation in Bremerhaven. The manufacturing capacities for the serial production of the M5000 for offshore operation are currently under construction on the Weser in Bremerhaven.

With these turbines Germany stepped into a new performance class, which is economically necessary in particular with offshore locations.

The third German 5 MW turbine, developed by the company REpower, was subsequently funded by the European Union and the Federal State of Schleswig-Holstein. The BMU tentatively held out the prospect for funding its offshore development in 2007.

After 15 years of research, the scientific measuring and evaluation programme by ISET (see above) was completed in 2006. Unique world-wide, the project included more than 15 years of operational experiences on 1,500 wind energy turbines, 63,000 reports on power production and maintenance, as well as 14,000 operating cost reports, and subsequently evaluated the wind supply (on a local and regional scale), operating results (energy supply, full load) and reliability (breakdown causes). With the help of 60 wind measurement stations nation-wide and data from the WMEP, procedures were developed for an on-line computation method for measuring momentary wind output, which is then fed into a electrical grid regulation zone.

With the help of computer-assisted neural networks, forecasts of wind energy output from 1 - 48 hours may be rendered from numeric weather forecasts. For years, the transmission system operators have used such forecasts in their daily operational planning. The accuracy of the subsequent day prognosis for the German grid amounts to about 5.7%, for the 4 hour prognosis, 3.6%. Developments will be continued in a research association of the ISET with energy sector enterprises (German Wind Monitor).

The research association OGOWIN is concerned with the optimisation of offshore foundations. OGOWIN consists of the Weser Wind GmbH, Hochtief Constructions AG, Europipe GmbH, REpower Systems AG, the Federal Institute for Materials Research, the Frauenhofer Society and the University of Hannover. Tasks include the development of cast nodes as connection joints of the pipes of so-called dissolved fundaments - i.e. latticed like structural steelworks for the anchorage of wind turbines on the seabed. Thus a toolbox of serial productions for such foundations is to be made possible. Included is the optimisation of the necessary assembly procedures on land and at sea, as well as the development of a long-term condition monitoring system for the foundations. Finally results should include substantial cost savings, an increase in efficiency during assembly and an improvement of the technical security of the foundations.

A study of the F+Z Baugesellschaft Ltd., which similarly concentrated on the offshore assembly of wind energy turbines and their fundaments, was completed in 2006. Based on market predictions for offshore installations in the Irish Sea, the North and Baltic Seas in the middle of the next decade of around 2,500 MW/a, with 550 fundaments /a, more than 400,000 tons of steel /a and a profit of around 1.2 billion Euros /a, a central platform was conceived, which is to ensure 75% availability in all seasons, even in harsh winter conditions. The availability of such offshore installation devices for the transport and construction at sea, proves to be a tightening bottleneck for the European offshore development both with regards to costs as well as weather-dependent supply.

Among the most important projects of the last years, the research platforms of the BMU are also to be given due attention. These will be formerly introduced in a separate contribution. The data supplied by FINO 1 in the North Sea has found a broad application and scope in ongoing research projects and in the wind industry since 2003. FINO 2 will be erected in June 2007 in the Baltic Sea and FINO 3 will follow in the summer of 2008 in the North Sea. Data gathered from FINO 1 as well as data from the future FINO platforms are/will be available online under valid user conditions on the following website: http://fino.bsh.de.

The depth and scope of the accompanying ecological research has achieved unique results worldwide concerning the possible influence of offshore wind farms on marine ecosystems. This ecological research was the main topic of the second day of 2nd Scientific Conference on the Use of Offshore Wind Energy by the Federal Ministry for the Environment, and is addressed in detail in other conference contributions.

Future Perspectives

A main emphasis of wind energy research supported by the BMU over the next years will be the offshore test site Alpha Ventus. The BMU has already appropriated 50 million Euros for this venture. The agenda of the research on the test site was co-ordinated by the operating company DOTI, together with equipment manufacturers and representatives of the scientific advisory board of the Offshore Foundation (Offshore-Stiftung). Significant projects, research network groups, as well as the research structures have already been conceived and classified according to priority in the funding planning of 2007. In the context of this test site research, the data gathered by FINO 1 will experience new applications.

Further new research activities include e.g.:

- the further development of multi-megawatt technology,
- the improvement of production procedures in the manufacturing process of multi-megawatt turbines,
- new foundation concepts for offshore wind energy turbines,
- investigations on the reciprocal effects between turbine fundaments and the seabed,
- development of equipment for offshore transport and assembly,
- technologies for sound reduction during the ramming of piles and fundaments,
- the analysis of problems and proposals for solutions regarding the behaviour of birds of prey and bats in relation to wind energy turbines.

Research programme of the Swedish government

Fredrik Dahlstrøm – Swedish Energy Agency

The Swedish wind pilot project

- Time period 2003-2007
- This is a project that in the long run will achieve technological breakthroughs and cost reductions in offshore wind power and wind power located near mountains.
- No fixed subsidy is being granted to projects, but final tender selection and economic grants will be divided up on an individual basis after negotiation.
- Projects will also include environmental studies, to answer some of the general questions involving wind power.
- The Swedish Energy Agency has a budget of 38M€.
- Most of the funding will go towards the additional cost of establishing wind farms offshore and near mountains.
- 40-50% of the additional cost of going offshore or near mountains.
- 100% in exceptional circumstances.
- Additional cost?
  - € 540 /kW
  - € 3.5 cent/kWh

Five Decisions

Projects	**Funding**
Kriegers Flak • Development of foundation • Marine navigation safety risk from offshore wind power • Flow and layer conditions	(***1,000,000 €***)
Lillgrund • 48 wind turbines of 2.3 MW (110.4 MW)	(***23,170,000 €***)
Utgrunden II • 20 wind turbines (90 MW)	(***7,600,000 €***)
Vindval • Environmental studies	(***3,800,000 €***)
Uljabuouda • 8-12 wind turbines (25-26 MW)	(***3,800,000 €***)

Vindval – a knowledge programme

- Aims to find out what impact wind farms have on people and the ecosystem.
- The programme is managed by the Swedish Environmental Protection Agency and funded by the Swedish Energy Agency.
- Its focus is on:
  - Effects of offshore wind power
  - Wind power located in mountainous areas.
- Topics identified as needing further study:
  - Local acceptance and landscape planning
  - Fish
  - Invertebrates
  - Birds & Bats
  - Sea mammals
- The budget is approx. 3,500,000 € and the programme will run from 2005 until 2009

Studies within Vindval

Local acceptance and landscape planning

- The socio-economic foundation of offshore wind power:
  - The overall aim is to identify how developers, investors, politicians, and officials communicate different working styles and can influence public opinion about actual plans for wind power developments in local marine environments.
- People and wind power
  - The aim of the study is to identify strategies for overcoming obstacles that may occur when setting up wind power.
- Better prediction of dose-response relationships for wind turbine noise and nuisance in hilly landscapes.
  - The project will answer four research questions related to:
    - the inadequacies of the present sound propagation models,
    - the importance of background sound levels,
    - the audio-visual load
    - peoples' expectations of their living environment

  as possible explanations for the variations between areas.

Fish

- Effects of offshore wind farms on fish (Vindval fish).
  - In this project the effects of environmental changes on fish will be investigated in four studies:
    - Effects on pelagic fish, (free swimming)
    - Effects on benthic fish, (sea bead)
    - Effects on spawning migration of eels,

        - GIS-based technique for mapping essential fish habitats on offshore banks.

- Acoustic disturbance of marine life by offshore wind farms
    - The aim of this study is to give guidelines for the construction of offshore wind farms. The objects of the project are to measure the relevant acoustic component, i.e. the particle acceleration, and relate the results to pertinent knowledge of fish reactions.
- Effects of acoustic disturbances by offshore wind farms
    - The knowledge gained from this project will reduce the uncertainties related to establishment of wind farms on the shallow banks in the open sea of the Gulf of Bothnia by simulating the sound generated by wind farms. The behavioural and feeding studies will be performed in the lab.

Invertebrates

- Benthic community structures and trophic interactions in offshore wind farms.
    - The aim with the study is to identify both general patterns that wind farms may cause and problems that are specific to each site.
- Effects and adaptations of marine soft bottom fauna to acoustic noise disturbances from offshore wind turbines.
    - This project aims to study changes in the behaviour and activity patterns of marine soft bottom fauna under the influence of low frequency noise from offshore wind farms.
- Environmental issues on optimising offshore wind farm foundations in relation to different bottom substrates
    - This project aims to incorporate the marine ecological aspects in the decisions on what foundations are to be used. The project will compile knowledge of construction techniques, apply marine ecology and present a practical assessment of how each foundation type influences the environmental aspects with different bottom substrates and depths.

Birds and bats

- Migrating passerines and waterfowl impact of a great offshore wind park
    - Study behaviour of migrating birds when they faced offshore wind park to create new knowledge. By using local radar equipment placed at Utgrunden lighthouse, which are on the bird migration main road and near the planned wind park Utgrunden 2.
- Bat casualty risks at offshore wind power turbines
    - The movements and behaviour of bats will be studied in relation to the turbines and their turbulence areas. The project will recommend the kinds of investigations that are needed before locating new windmills and methods to minimise casualty risks.
- A bird's eye view of offshore wind power
    - The colour vision system of birds and humans differ in many important respects. This study will use the vision physiology of the bird species to calculate an estimate of the perceived contrast between offshore wind farms and their background during diverse weather conditions and at different times

of day. With this knowledge one can calculate the optimum coloration of the wind turbines for increased visibility to birds and decreased disturbance to humans. This should minimize bird collisions as well as preserve esthetical values in the natural surroundings.

Wind pilot project, episode 2

- 2008 - 2012
- Budget M€ 39
- Stronger focus on onshore than previous round
- Evaluation of the effects of previous investments.

Marine renewable energy – UK government & cooperative research

Summary of the Presentation by John Hartley – Department for Trade and Industry, UK
written by Leena Morkel – TU Berlin

UK wind energy context

In 2003 in the UK in the Energy White Paper a target of generating 10% of electricity supply from renewable energy by 2010 was set by the government. In 2006 the UK Energy Review Report "The Energy Challenge" included the aspiration to derive 20% of UK electricity from renewable sources by 2020. In the last 20 months the amount of wind generated electricity in the UK has doubled. The recently consented London Array and Thanet offshore wind farms will together produce in total 1,3 GW enough to power a third of London's three million households.

UK marine sensitivities to be considered in context to the implementation of offshore wind energy

- Birds
- Seals
- Cetaceans
- Fish
- Seabed fauna and features
- Archaeology
- Navigation routes
- Fishing grounds
- Other users
- Numerous coastal, marine and offshore Natura 2000 sites

UK offshore wind farms environmental research

The UK has a number of Government and Cooperative environmental research initiatives for marine renewable energy. Individual UK Government Departments and Agencies fund targeted environmental research, guidance development etc. COWRIE (Collaborative Off-shore Wind Research Into The Environment), BWEA (The British Wind Energy Association) and others fund offshore wind environmental research and guidance development. A pan Government Research Advisory Group (RAG) was established to facilitate a co-ordinated approach to address key issues.

What is the research advisory group (RAG)?

The cross UK research advisory group was initiated in 2003. It facilitates a co-ordinated approach to addressing the key environmental issues for all marine renewable energy. Those departments with regulatory responsibility for wind farms are members of the RAG, i.e. the Department of Trade and Industry (DTI), the Department for Environment, Food and Rural Affairs (Defra) and Department for Transport (DfT), and the Crown Estate. The research topics have been grouped into themes and each assigned a theme leader.

How RAG works

The group constituted terms of reference. They meet regularly and called theme leaders that are responsible for the different topics of research. The RAG prioritised research topics that are competitively tendered. The study results are available to the public and can be downloaded on the website.

RAG milestones

The RAG compiled a list of issues and concerns raised about marine renewables. Initially it contained just wind, now it also includes wave & tidal stream. Lately a combined RAG & COWRIE list of Environmental Issues and Research Topics has been derived and a cross membership of RAG & COWRIE exists. The RAG initiated a series of reviews, studies and other activities.

The completed research activities include:

- Aerial surveys for birds.
- Boat based training for bird surveyors.
- Guidance on seascape visual impact assessment.
- Methodology for assessing marine navigation safety risks of wind farms.
- Wind farm decommissioning financial security study.
- Radar trials in wind farms.

Other RAG projects are still underway:

- Review of cabling techniques & environmental effects.
- Review of reef effects of offshore wind farm structures and potential for enhancement and mitigation.
- Review of round 1 sediment process monitoring data – lessons learned.
- Review of navigation channel migration.
- GPS location tags to monitor seal interactions with tidal stream turbine.
- Energetic costs of barrier effects on birds.
- Review of round 1 benthic monitoring data – lessons learned.

Currently planned RAG projects are the following:

- Strategic reviews of potential environmental issues for marine renewable developments.
- Reviews of monitoring data from wind farm and other renewable developments.
- Studies to contribute to SEA baseline understanding.
- Development of techniques and methodologies.

- Conferences to disseminate results.

The future RAG projects selection will be guided by:

- Wind, wave and tidal stream research strategy.
- Combined RAG/COWRIE issue list.
- Stakeholder input e.g. OREEF (Offshore Renewables Energy Environmental Forum).
- UK & other experience of marine renewable demonstrators & developments.
- Information needed to inform policy.

Challenges and opportunities of RAG

More solid evidence needed of effects & context of natural variability.

- Data management and access.
- Numerous initiatives & funding sources.
- Coordination and cooperation.
- Balance of effects - local vs global.

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The Danish monitoring programme - Horns Rev and Nysted offshore wind farms and experiences with the German-Danish research cooperation

Summary of the Presentation by Steffen Nielsen – Danish Energy Authority
written by Leena Morkel – TU Berlin

Advantages of wind power

The objective of supporting the use of wind power and particular offshore wind power has in a historic perspective been environmental matters and energy import alleviation. In recent years security of supply, export and employment also arrived on the political agenda.

15 years of experience offshore

Denmark already has 15 years of experience with the use of offshore wind energy. The first Danish offshore wind farm was established in 1991 as a pilot project, followed by a couple of other pilot projects in 1995 and in 2000. The offshore wind capacity that is actually installed in Denmark is about 423 MW. Two other future projects, each with 200 MW, have been tendered for the establishment in 2009 and 2010. An assessment for future locations of large-scale offshore wind power will be published soon.

Tenders for 2 x 200 MW - aim to reduce financial risk

For the tenders, it has been attempted to reduce financial risks in order to receive the best price for the development. The philosophy has been to reduce all uncertainties for the developer engaging in offshore wind, for example:

- One stop shop communication.
- Screening for mature site suitability.
- Cheapest, fastest and most elegant wind farm design.
    - Fixed price in 50,000 full load hours.
    - TSO to finance, construct and operate transformer station and sea cable.
    - Security that grid connection is available in due time.
    - Financial compensation if the power produced is curtailed.

The licensing process for the two 200 MW offshore wind farms has been arranged in a consent procedure. First there was a political decision allowing for altogether 400 MW. Tenders have been undertaken and concessions have been granted. As part of the concessions a licence was given to undertake pre-investigations on the sites. The environmental impact assessment for the Horns Rev II has already been carried out. All public comments are currently being evaluated. A new environmental impact assessment is going to be carried out for the Nysted wind farm later on this year. On that basis, a concession is granted and when all applications are fulfilled, including also obligations to do environmental monitoring, a licence for the wind farm will be given and it can be installed.

Preparing for the future, 2025

The federal government presented a very ambitious energy plan for the future this past January. Its aim is to have at least 30% renewable energies as a part of the whole energy consumption including transport by the year 2025. This aim should be achieved on the one hand by energy saving and on the other hand by using renewable energies with the focus on biomass and wind power.

The future of offshore wind power utilisation in Denmark involves a strategic mapping (Future Offshore Wind Turbine Locations – 2025", published in April 2007). The Committee for Future Offshore Wind Turbine Locations made a strategic environmental impact assessment for the mapping for future locations of offshore wind power use. This also updates the "The Offshore Wind turbine Action Plan for Danish Waters" from 1997. The main issues assessing possibilities for the location of future offshore wind farms are:

- wind resources,
- distance to shore,
- water depths,
- grid connection,
- nature and environment,
- shipping,
- other area interests.

The report charts a number of possible offshore areas where offshore turbines could be built to an overall capacity of some 4,600 MW. Offshore wind turbines with a capacity of 4,600 MW could generate approximately 18 TWh, or just over 8% of total energy consumption in Denmark. This corresponds to approximately 50% of Danish electricity consumption. The committee has examined in detail 23 specific possible locations each of 44 square kilometres to an overall area of 1,012 square kilometres divided between 7 offshore areas.

Demonstration wind farms

The two demonstration wind farms installed in Danish waters are Horns Rev in the North Sea and Nysted in the Baltic Sea.

Horns Rev offshore wind farm

Horns Rev offshore wind farm was commissioned in 2002. It has 80 wind energy turbines from Vestas (V80 2MW). In total 160 MW are installed. The wind farm is built in a water depth of 7-14m in a sandy seabed. Its distance to the coast is 14-20km. The foundations type used for the wind energy turbines is the monopile.

Nysted offshore wind farm

Nysted offshore wind farm was commissioned in 2003. It has 72 wind energy turbines from Bonus (2,3 MW), with a total of 166 MW are installed. The foundation type used for the turbine is a concrete caisson. The wind farm is built in a water depth of 6-10m in a sandy seabed on hard clay. Its distance to the coast is 10km.

Administrative set up

Already in 1999, a pre-investigation in the two wind farm areas had begun. The administrative set up with the demonstration programme was publicly funded. Results are now available in the book – "Danish Offshore Wind – Key Environmental Issues". The background reports are also available on www.ens.dk. The programme was managed by the so-called Danish environmental group consisting of:

- the Danish Energy Authority,
- the Danish Forest and Nature Agency,
- DONG Energy and
- Vattenfall

An international panel of experts has also evaluated the programme during the years.

Overview of the monitoring programme

It is a quite comprehensive programme covering all the major issues regarding potential environmental effects on the marine environment. It involves the following issues:

- Hydrography
- Coastal morphology
- Benthic fauna
- Artificial reef effects
- Fish
- Electromagnetic fields
- Temperature gradients around the cable
- Submarine noise emission
- Birds
- Seals
- Harbour porpoises
- Socio- and environmental economic effects

Most of the studies followed a BACI design (**b**efore / **a**fter and **c**ontrol / **i**mpact). **B**efore means that studies have been made before the wind farms were built and **a**fterwards. Also studies have been done in a **c**ontrol area away from the wind farm.

Conclusions from the environmental programme

Public acceptance was found. The local people had mostly a positive attitude to the wind farms. Especially Horns Rev was well accepted by the people. Whereas in the Nysted areas, the people had more concerns about it because it was placed closer to the coast line.

An avoidance behaviour by birds has been observed. This behaviour minimizes the collision risk for migrating birds. Also resting birds avoid the wind farm areas, but a tendency for habituation of these birds (common sculls) has also lately been detected.

The behaviour of seals seems not to be affected. They fled from the area during the ramming of piles and construction period as presumed and returned when the construction work was finished.

Harbour porpoises seem to have a similar behaviour as seals. They returned to the area after the construction works. At Horns Rev the returning time of harbour porpoises was shorter than at the Nysted wind farm.

A significant "artificial wreck effect" was observed. It is expected that this will lead to a larger degree of biomass and diversity within the wind farms.

German-Danish cooperation on environmental research for offshore wind energy deployment

The objective of this international cooperation is it to intensify the cooperation in research on the impact of offshore wind power on marine environment. It should strengthen the transfer and exchange of know-how and information between the parties and carry out joint research projects.

Administrative set up

The cooperation has been set up in a governmental declaration between Germany and Denmark. A steering group at the ministerial level meets regularly and discusses various matters around the use of offshore wind energy. The parties share data among each other including raw data. The German Ministry for the Environment primarily finances studies that are made within the cooperation. The coordination and correlation to the Danish studies is funded by Denmark.

Previous studies within the Horns Rev and Nysted wind farm areas

Studies that have been undertaken within the international cooperation include the following:

- Bird studies with focus on collision risk. They are supplementing the Danish studies in terms of methodology and parameters studied (focus on flight altitudes).
- Responses of harbour porpoises to the wind farms. Using T-POD's, supplementing the Danish studies in terms of level of spatial detail (focussing more on the immediate vicinity of the wind farm).
- Underwater measurements of noise emission.
- Temperature measurements in sediments near cables.

Future activities

Future research activities within the cooperation are already planned. There will be a follow up on the Danish monitoring programme:

- EIA on Horns Rev 2 and Nysted/Rodsand 2,
- Common Scoter at Horns Rev 1 & 2.

There are also German research projects in Horns Rev and Nysted in discussion for 2008 that deal with

- bird collisions and
- harbour porpoises.

International co-operation

For international cooperation, the sharing of information is obviously necessary. This must be done in an ongoing process. Maybe also in the following work of:

- OSPAR
- EWEA
- New COD (could be established)?

The cooperation should not only be based on the two countries Germany and Denmark. It should be held as a joint cooperation. It can be extended by:

- An offshore working group in technology platform within the European Union is expected.
- Other countries should join the D-DK agreement. This cooperation is able to open up to other participants and maybe also for other types of research, rather than just environmental research.
- Common research projects

More information about the Danish programme on the use of offshore wind energy can be found on the website of the Danish Energy Authority www.ens.dk.

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Bird migration over the North Sea

Dr. Ommo Hüppop & Dipl.-Geogr. Reinhold Hill
Institute of Avian Research “Vogelwarte Helgoland”, Inselstation Helgoland
Translation: Alexandra Toland, Leena Morkel – TU Berlin

Introduction

With respect to the natural asset „bird migration“ (in this case also including bat migration), the following aspects are to be regarded:

- Affected species,
- Seasonal intensity of migration,
- Diurnal/nocturnal intensity of migration,
- Absolute number of individuals,
- Spatial distribution of migration,
- Altitudinal distribution of migration,
- Orientation / Collision,
- Population trends of the most significant species.

Existing knowledge about bird migration over the open North Sea is briefly summarized as follows (e.g. HÜPPOP et al. 2006):

- The amount of basic data is notably lesser than data on migration over land,
- The greater part of migration occurs at night,
- Migration over the German Bight presumably occurs as a broad front but tapers off towards the open sea,
- Migration intensity is extremely variable on a sudden, short-term basis,
- The migration is based on wind related and seasonal conditions,
- A high proportion of migration occurs at lower altitudes,
- Bats also regularly migrate over the open sea.

In relation to the previous scientific conference, the database could be substantially extended and thus the level of knowledge considerably increased and/or confirmed. In the following, selected results are to be presented with regard to some of the issues outlined above. The methods used in our research are described in detail in HILL & HÜPPOP (2007), so that it is not necessary to address these here.

Annual and diurnal migration intensity

Apart from certain data gaps due to technical complications, data results gathered from a vertically rotating marine radar on the research platform FINO 1 provide a comprehensive account on the yearly and daily intensity of bird migrations from the autumn of 2003 up to the present (fig. 1). In addition to the already well-known intensity of migratory movements in the spring and autumn, it has become quite clear that the migration is concentrated to just a few „migratory waves“ per migration period, and that the greater part of migration takes place at night. Intensive migrations during the day occur for the most part in the summertime.

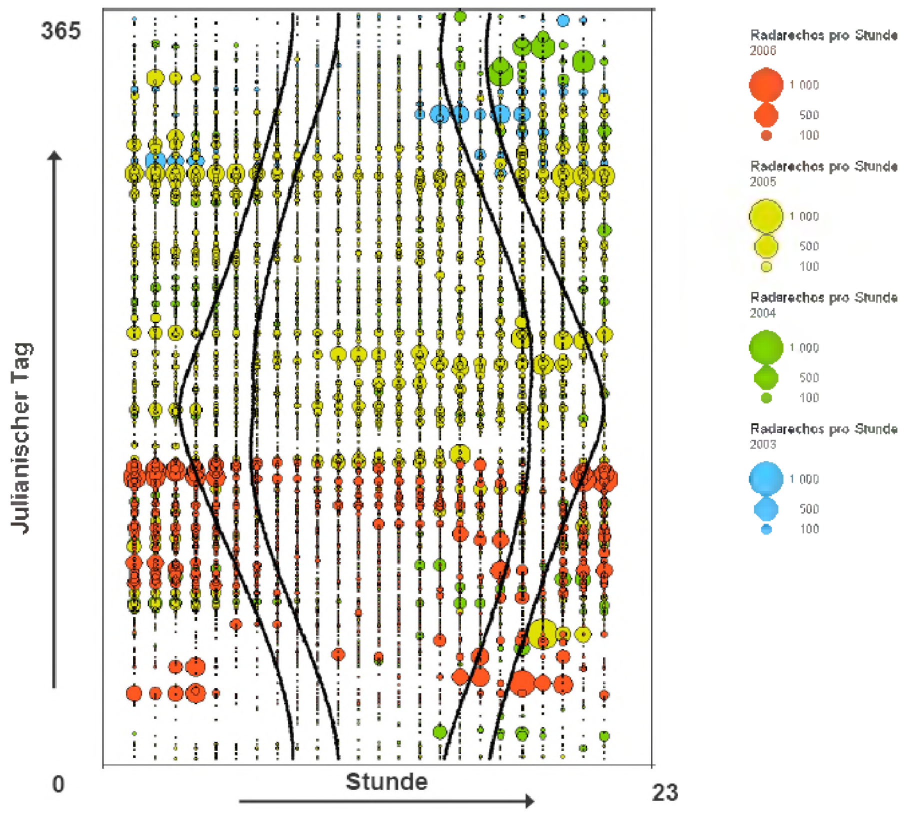

Figure 1: Migration intensity according to data gathered from a vertically rotating marine radar (12 kW) on the research platform FINO 1 from autumn 2003 to spring 2006. Illustrated above are expenditure-corrected radar echo totals per hour, but not showing data gaps caused by technical complications. The bold dotted black lines mark twilights (position of the sun -9° under and/or +9° over the horizon).

Radar echoes naturally provide no information about the species spectrum involved. Audio recordings of species-specific migratory calls prove to be especially helpful in migration surveys (FARNSWORTH 2005). The three most common thrush species (*Turdidae*) in Northern Germany often call during migration. Their calls were mainly recorded at night (fig. 2), with a few calls during the day presumably from birds resting on the platform. There appears to be a clear temporal differentiation between the three species in terms of seasonal phenology, which is supported by migration patterns determined by captures on the island of Helgoland, 90km to the east (fig. 3). This emphasizes the suitability of standardized recording of migratory calls for the study of migration phenology in frequently calling birds (see also discussion in FARNSWORTH 2005). The vernal migration of the Blackbird (*Turdus merula*) was nevertheless only occasionally observed on the FINO 1, in contrast to the trappings on Helgoland.

The majority of the migratory calls of thrushes were registered in the second half of the night, above all with an observed intensity just before dawn on some nights. This information corresponds to various observations of songbirds in North America (FARNSWORTH 2005), but contradicts the observations of VLEUGEL (1960) and other authors on European thrushes. The differences may be explained by the situation of the platform located far out at sea.

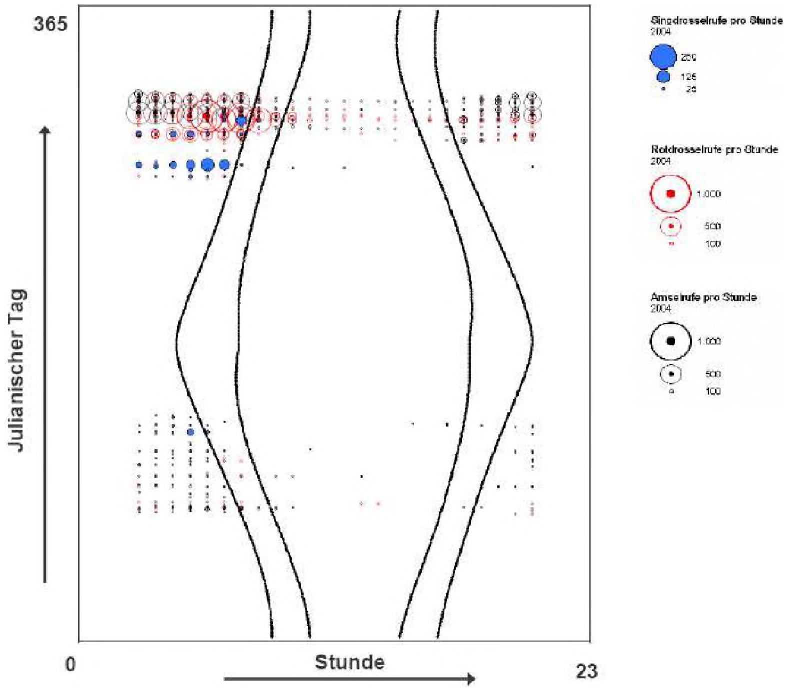

Figure 2: Phenology of Song Thrush, Redwing and Blackbird (*Turdus philomelos, T. iliacus, T. merula*) according to acoustic recordings made on the research platform FINO 1 (calls per hour). The bold dotted black lines represent twilights (position of sun 9° under / over the horizon).

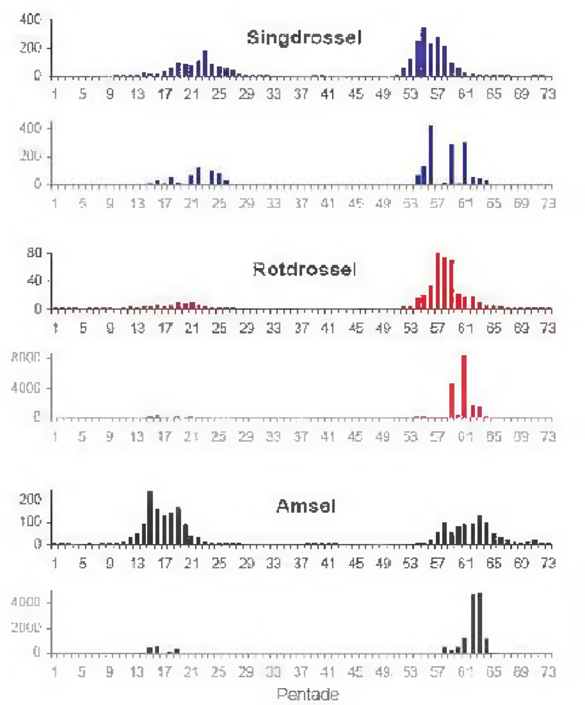

Figure 3: Migration phenology of Song Thrush, Redwing and Blackbird according to acoustic recordings made on the research platform FINO 1. in the year 2004. Grey axes represent the sum of migratory calls for every 5 days, which are compared with capture numbers over many years on Helgoland (black axes represent the mean number of captures per 5 days from 1991 to 2000; HÜPPOP & HÜPPOP, 2004).

Calls of Common Starlings (*Sturnus vulgaris*) were recorded both in the spring and even more so in the autumn (fig. 4). The Starlings were recorded mainly at night, similar to Common Redshanks (*Tringa totanus*), who were almost exclusively recorded during their autumnal migration at night. In contrast, calls of the Sandwich Tern (*Sterna sandvicensis*) were nearly only recorded by day. This was apparent particularly after the breeding period, in which intensive migration was registered in the area around the FINO 1 platform and/or resting birds were observed on the platform itself (terns only rarely swim). In individual cases some breeding birds of the East Frisian Islands may also forage in this area (see GARTHE & FLORE 2007). The frequent appearance of Sandwich Terns on the FINO 1 platform indicates that special attention must be dedicated to the further observation of this species during and after the construction of the pilot wind farm. Recent studies show that terns are apparently at greater risk of collision (EVERAERT & STIENEN 2007), even though they are almost exclusively diurnally active. As on the research platform terns also like to rest on structures in wind farms. Germany carries moreover a high international responsibility for the protection and conservation of Sandwich Terns (GARTHE & FLORE 2007).

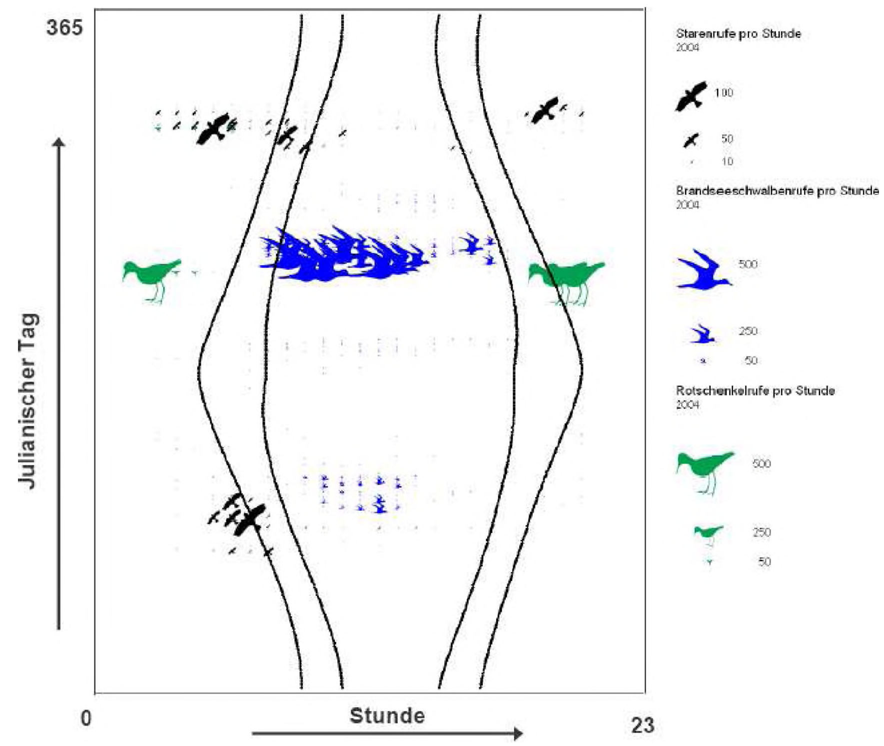

Figure 4: Phenology of Starling, Sandwich Tern and Common Redshank (*Sturnus vulgaris, Sterna sandvicensis, Tringa totanus*) according to acoustic recordings made on the research platform FINO 1 (calls per hour). The bold dotted black lines represent twilights (position of sun 9° under / over the horizon).

Collisions

Of the 586 dead birds found on 93 visits to the FINO 1 platform from October 2003 to July 2006, four out of five were thrushes (primarily Redwings and Song Thrushes), 8% were Starlings, and less than 5% included all other bird species (fig. 5). A more exact investigation of a larger sampling (n = 439) of cadavers showed that three out of four birds clearly had discernable external injuries, and were therefore most likely collision victims. Since more than 90% of the remaining birds exhibited a body condition (fat content > 0), which could have sustained further flight, these cases too are assumed to have been victims of collisions. Only about 2% of all birds exhibited such weakened physical conditions (fat content = 0) that a circumstantial „emergency landing“ on the platform is to be assumed.

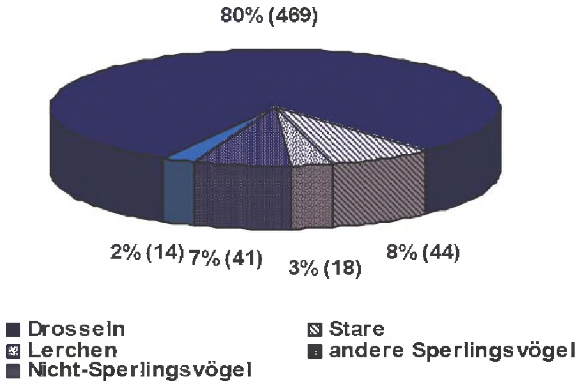

Figure 5: Species-specific distribution of dead birds found on the FINO 1 platform on 93 visits from October 2003 to July 2006 (n = 586).

Bat migration

From the beginning of the FINO 1 acoustic recordings in August 2004 up to August 2006 and from February to June 2007, 7 incidences of ultrasonic calls from 2 different bat species (Nathusius' Pipistrelle *Pipistrellus nathusii* 6 x, Serotine Bat *Eptesicus serotinus* 1 x) were registered. These numbers are clearly fewer than observations taken over the same time period on the island of Helgoland (HÜPPOP, in prep.), but indicate however a regular migration of bats over the open North Sea. It has also to be noted here that migrating bats presumably „switch off“ their ultrasonic echolocation system temporarily, which can lead to deadly collisions with stationary objects (VAN GELDER 1956, CRAWFORD & BAKER 1981), and render the movements acoustically undetectable as well. From the recorded sounds it can be concluded that at least some individuals probably hunted insects on the FINO 1, which were possibly attracted by the lighting on the platform. This could increase the risk of collision for bats.

Summary

1.) There is considerable variation in migration intensity (seasonally, diurnally/nocturnally, species-specific, but also from year to year).
2.) The majority of birds migrate in two to four „migratory waves“, especially during the night.
3.) The acoustic recordings of bird calls provide important data about the species spectrum and phenology.
4.) Thrushes represent the greatest number of collision victims on the FINO 1; non-songbirds represent only 2%.
5.) 75% of all collision victims bear signs of external injury; > 90% of the remaining birds exhibit a body condition, which could probably sustain further flight.

6.) Drizzly rain and strong wind gales probably increment the risk of collision.
7.) The migration of bats over the open sea could be proven by acoustic recordings of ultrasonic location signals.

Acknowledgements

We would like to thank our co-workers and colleagues from various projects for their cooperation and support. Above all we would like to thank our sponsors:

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Bird migration across the Baltic Sea

J. Kube, J. Bellebaum, A. Schulz, H. Wendeln

Approximately 1 billion birds from Scandinavia and western Siberia cross the western Baltic Sea, the Danish Isles and parts of the German Bight twice annually. There are about 250 abundant species involved. The largest group of migrants are passerines migrating either during night or day (95% of all birds). The analysis of ringing results, especially short-term recoveries, is a useful tool to describe their species-specific migration routes. Western migrants, by far the largest group of Scandinavian passerines crossing the western Baltic Sea, breed predominantly in Sweden and western Finland. Norwegian landbirds preferably cross the North Sea and the Danish peninsula, whereas birds from eastern Finland usually cross the Gulf of Finland during autumn migration. Many breeding birds from western Siberia follow along the south coast of the Baltic Sea. Although, the overall direction of migration for western migrants is 210°, individuals follow specie s-specific spatial, seasonal and diurnal pattern.

The tremendous variety of migration strategies, flyways and flight behaviours requires the application of different methods for the quantification of active bird migration. Sea watching is a useful tool to quantify diurnal waterfowl migration at low altitude. A larger network of sea watching points along shores can be used for the spatial description of waterfowl flyways. In contrast, diurnal passerines can be detected by eye only up to 50m altitude. Only up to 5 % of the birds aloft can be registered by this method, therefore. Investigations by tracking radar, carried out on Rügen Island in autumn 2005 revealed an average altitude of about 1,000m for diurnal passerine migration during optimal flight conditions (tailwind). Most diurnal passerines migrate in flocks. Thus, the analysis of radar data cannot be used to quantify diurnal passerine migration, because the analysis of single echoes does not allow for a quantitative approach. In contrast, birds migrating at night predominantly fly separately. Investigations by fixed beam radar, carried out on Rügen Island in autumn 2005 revealed less than 8 % of echoes with signal pattern presumably related to bird flocks. About 5 % of all echoes could be attributed to non-passerine birds. Thus, about 85 % of all registered echoes could be assigned to nocturnal passerines (55 % thrushes, 35 % small passerines, 10 % goldcrests & wrens). Tracking radar and fixed beam radar, therefore, are useful tools for the quantification of birds aloft during night. Furthermore, they can be used for a qualitative approach of bird flight behaviour and size by the analysis of wing beat frequency and wing beat pattern.

Distribution of seabirds in the North and Baltic Seas

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Abstract

About 35 species of seabirds occur in the German North and Baltic Seas. They include birds of the high seas and the coastal zones but also birds that breed on freshwater lakes and winter at sea. They are distributed differently over the German marine areas. Some species feed on prey at the sea bottom (molluscs) while others feed primarily on fish. Some seabird species feed on a variety of prey categories and are thus called omnivores. The various seabird species exhibit different seasonal distribution patterns over the year, but fluctuate also at much shorter time scales. Examples for seasonal variations are given for the Common Eider (Somateria mollissima) in the Baltic Sea while the Black-legged Kittiwake (Rissa tridactyla) has been chosen to study short-term variability in distribution patterns in the southeastern North Sea.

Seabirds in German marine areas

There are about 35 different bird species that regularly appear in the coastal areas of German waters (GARTHE et al. 2003a). These marine species will be referred to in the following as seabirds, as they use the sea exclusively or partially for foraging and resting purposes. Species, which only fly over the sea and rest for short periods of time if necessary, are for the most part migratory birds, which are to be categorized with the terrestrial birds.

Of the species composition of seabirds in the German North and Baltic Seas, it is characteristic that typical high seas species occur less frequently while species occurring in both fresh water habitats as well as coastal areas dominate in number. Among the high seas bird species are the Northern Fulmar (*Fulmarus glacialis*), the Northern Gannet (*Sula bassana*), the Black-legged Kittiwake (*Rissa tridactyla*) and the Common Guillemot (*Uria aalge*). These species are widespread in the entire North Sea and adjacent northeast Atlantic, and reach the edge of their geographical range in the German coastal waters. The first three mentioned species are observed only rarely and in small numbers in the western Baltic Sea (SONNTAG et al. 2006). Divers (Red-throated Diver, *Gavia stellata* and Black-throated Diver, *Gavia arctica*) and Grebes (Slavonian, Red-necked and Great Crested Grebe, *Podiceps auritus*, *grisegena* and *cristatus*) breed on fresh water lakes and ponds in Scandinavia and the Baltic region and use the shallow marine areas, in particular the southern areas of the Baltic Sea, only outside of their breeding season, i.e. during migratory periods and in the winter.

Different species of gulls quantitatively dominate the offshore areas of the German North Sea, breeding along the Wadden Sea coast (the Lesser Black-backed Gull, Herring Gull and Common Gull; *Larus fuscus*, *argentatus* and *canus*) or on Helgoland (above all the Black-legged Kittiwake, *Rissa tridactyla*), or appearing as migratory and winter guests (the Little Gull, *Hydrocoleus minutus* and the Great Black-backed Gull, *Larus marinus*; MITSCHKE et al. 2001, GARTHE 2003). The occurrence of sea ducks in the German Baltic Sea is also worth mentioning. While these species breed along the Baltic Seashore - here particularly in the north and east – large numbers of ducks spend most of their time outside of the breeding season in the southern Baltic Sea. Midwinter population surveys amount to about 242,000

Common Eiders (*Somateria mollissima*), 596,000 Long-tailed Ducks (*Clangula hyemalis)*, 177,000 Common Scoters (*Melanitta nigra*) and 51,000 Velvet Scoters (*Melanitta fusca*; GARTHE et al. 2003b). A noteworthy peculiarity is the occurrence of Common Scoter on the Oderbank during summer and/or moulting periods. These figures fluctuate sharply but can reach up to 220,000 individuals (SONNTAG et al. 2004).

The search for food is a substantial characteristic, which determines the distribution patterns and behaviour of birds at sea. The species of seabirds occurring in German marine areas can be principally organized into three main categories of food preference: (1) benthos, or bottom feeders (mainly molluscs), (2) fishers and (3) omnivores. The sea ducks are the most prevalent bottom feeders, while the divers, Northern Gannets, Great Cormorants (*Phalacrocorax carbo*), terns and auks make up the fishers and the gulls and fulmars belong to the omnivores. Species belonging to the latter feeding category are summarized as having a very wide food spectrum – they forage for food on land, on the benthos of the Wadden Sea as well as on fish and plankton from the sea (GARTHE 2004).

Spatial and temporal distribution patterns

As a result of long-lasting investigations by the Seabirds at Sea Programme (GARTHE & HÜPPOP 2000) as well by intensive project funding both in the context of the accompanying ecological research for offshore wind energy and the establishment of European Union bird conservation areas (Important Bird Areas) at sea, there is a large database of the occurrence of seabird populations in German marine areas. It is therefore possible to reproduce comprehensive representations of seasonal distribution patterns of all species and to make rough estimations concerning population survey figures. However, depending on spatial-temporal associations, knowledge gaps still remain with regard to larger surfaces of the water. Such insufficiencies can only be partially resolved due to the immense logistic and financial expense.

In the last few years, special attention was placed on temporal fluctuations in distribution patterns, and above all on seasonal changes and short-term changes within single seasons. In the following, one example is given for regional, seasonal fluctuations in the Baltic Sea, and one example for short-term, small-scale fluctuations in the North Sea.

Almost all species of seabirds in German marine areas show strong fluctuations in their frequency and distribution patterns over an entire year. Four basic phases can be determined for all bird species, which are furthermore referred to as seasons. The breeding period and/or summertime is the phase of the year, in which sexually mature individuals participate in breeding activities. Non-breeders and juvenile birds often spend this time far away from future breeding sites. The autumn and/or the autumnal migration is the phase, in which the birds vacate breeding and/or summer locations and retreat into their wintering areas. These migrations can carry on over many weeks, and are often characterized by larger accumulations of individuals during resting periods. After the breeding season and autumnal migrations, the birds spend their time in winter areas. The winter season can contain regular fluctuations of different sites, and is often not entirely separate from the autumnal and vernal migration periods. The vernal migration and/or springtime is the phase, in which the birds leave their winter quarters and return back to their breeding spots and/or summertime sites.

The seasonal pattern of the Common Eider is demonstrated in fig. 1 on the basis of long term results of ship counts. This species breeds only in small numbers along the German Baltic Seashore (2000: 39 pairs; GARTHE et al. 2003b), and accordingly only a few animals spend their time in close proximity to the coast. Large numbers of Eider Ducks gather in the

Schleswig-Holsteinian and Mecklenburgian parts of the German Baltic Sea from autumn to spring, while only a few animals have been sighted along the Vorpommeranian coast and in the Pommeranian Bay. Apart from differences in seasonal frequency in the western part of the Baltic Sea, year round spatial differences are clearly observed between the western and eastern parts of the German Baltic Sea. Despite certain mapping gaps in the Kieler Bay in winter, it is still evident that the highest abundance of Eider Ducks appears in autumn and winter, while the occurrence clearly thins out over the spring (SONNTAG et al. 2006).

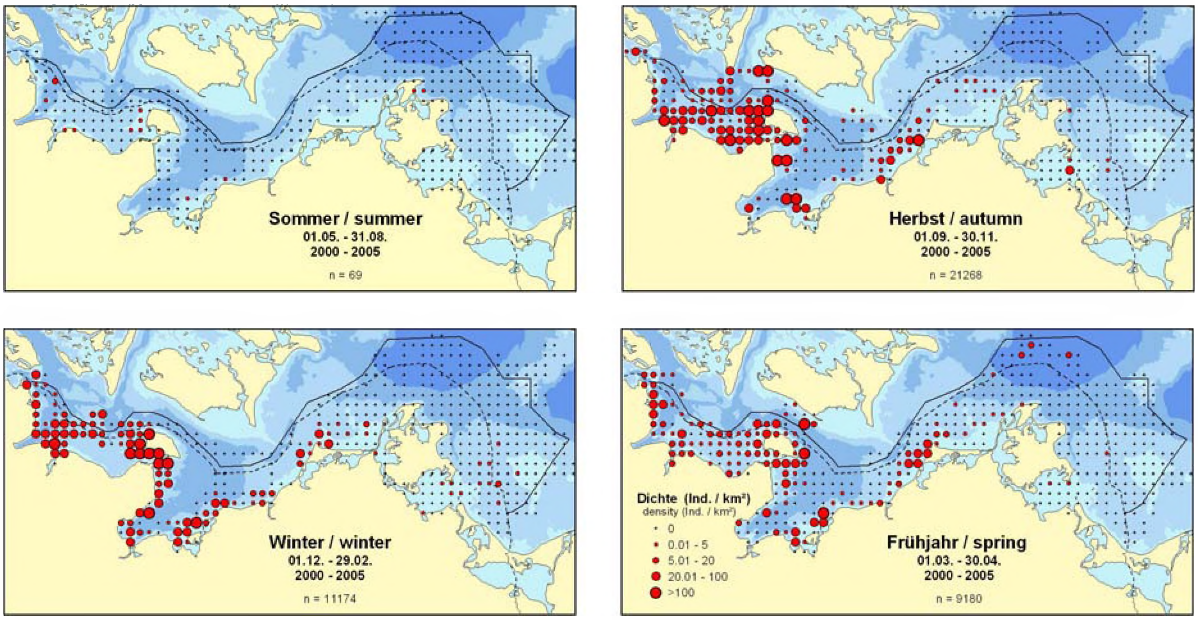

Figure 1: Annual Distribution of Common Eiders in the German Baltic Sea (SONNTAG et al. 2006)

Within different seasons, seabirds also demonstrate fluctuations in the spatial extent of their distribution at sea. During the breeding season, birds are generally bound to their breeding spots, e.g. to relieve the nesting partner or to supply the chicks with food. Certain variability between individual days is nevertheless to be expected here as well. Since the food for seabirds is unevenly distributed at sea and is likewise characterized by its own spatial-temporal fluctuations (e.g. HUNT & SCHNEIDER 1987), a variability in the distribution of foraging seabirds is also to be expected. By examining series of brief sequential flights, breeding birds of Helgoland were studied with regard to daily variability over the summer of 2006.

The distribution patterns of the Black-legged Kittiwake differed in several areas between July 12 and 13, 2006 (fig. 2). As expected, the main occurrence both days was around the breeding area on the island Helgoland. On July 12 the foremost occurrence was observed in the northwest of the island, but could no longer be accounted for on July 13. Subsequently, the abundance of birds on the second day was observed in western and eastern parts of Helgoland on a much larger scale than on the first day. One explanation supposes that such fluctuations are a result of the changing availability of food for the Black-legged Kittiwake, which raises its young during this time.

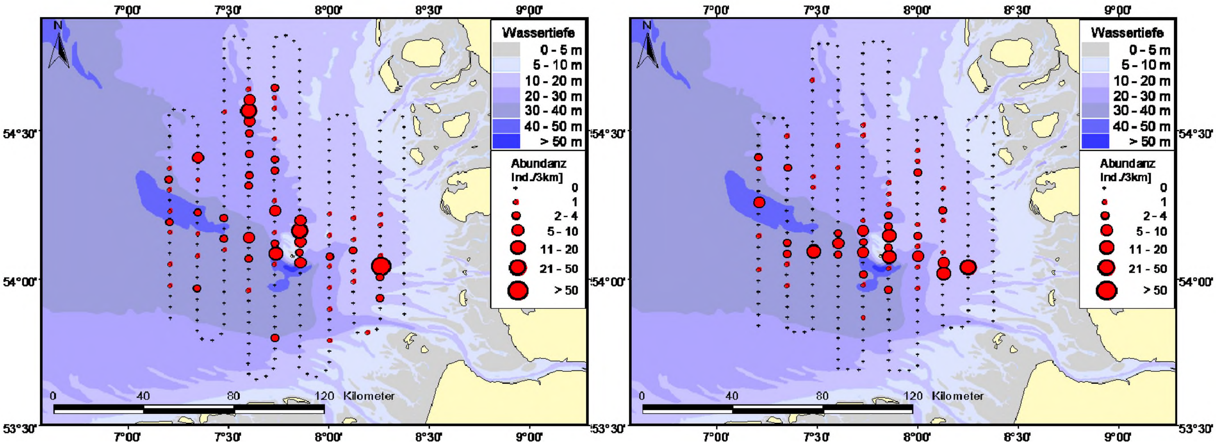

Figure 2: Distribution of the Black-legged Kittiwake in the German Bay from July 12 to 13, 2006

Future prospects

After successfully describing the distribution patterns of seabird species in the German North and Baltic Seas over different temporal and spatial dimensions, the emphasis now lies in analysing those factors, which cause such distribution patterns and their variability. In addition, it is necessary to develop long-term data sequences in order to be able to measure population changes and potential consequences of human influences (e.g. environmental impacts and/or climate change).

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Abundance estimates and habitat use of harbour porpoises in the German North and Baltic Seas

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Abstract

Harbour porpoise density and distribution have been investigated for the past several years in the German North and Baltic Seas with the help of aerial surveys and acoustic monitoring. Results show geographical differences as well as seasonal variation in the density and distribution of the German harbour porpoise stock. In the summer more porpoises were present in German waters than in the winter. In the North Sea densities declined from North to South, whereas in the Baltic Sea, the trend went from West to East. Permanent porpoise occurrence and highest densities in the summer identified Sylt Outer Reef as an important harbour porpoise habitat. In the German Baltic Sea (including adjacent Danish waters), porpoise density was ten times lower than in the German North Sea. In this area, acoustic monitoring proved to be effective and valuable. Both methods are very efficient for investigating the actual density and distribution of harbour porpoises in the German North and Baltic Seas.

The harbour porpoise

The 1.80m long harbour porpoise belongs to one of the smallest species of cetacean. It weighs up to 90 kg and has a life expectancy of about 25 years. Its diet consists of fish such as whiting, cod, herring, and sand eel (SCHULZE 1996, SANTOS & PIERCE 2003).

At the turn of the last century the harbour porpoise was still common throughout the Baltic Sea (cited in KOSCHINSKI 2002). Its population size and area of distribution has decreased severely within the last several decades (BENKE et al. 1998, KOSCHINSKI 2002, SIEBERT et al. 1996).

The Research and Technology Centre of the University of Kiel and the German Oceanographic Museum have different research focuses, which provide important knowledge about the harbour porpoise stock in the North and Baltic Seas. They include the evaluation of data that are obtained e.g. through the collection of strandings and incidental sightings.

Acoustic monitoring and visual surveys are carried out within the framework of funded research projects[1]. This will be presented in the following.

[1] **MINOS** (FKZ 0327520) **and MINOS**^{plus} (FKZ 0329946B/C)**:** Marine warm-blooded animals in the North and Baltic Seas: Foundations for assessment of offshore wind farms; **EMSON:** Census of marine mammals and seabirds in the German EEZs of Baltic and North Sea. FKZ 80285260; **JASTARNIA:** Investigations on Harbour Porpoises in the Baltic Sea as Basis for the Implementation of the Recovery Plan for Baltic Harbour Porpoises (Jastarnia Plan). FKZ 80486011–K1.

Visual survey

Methods

The visual survey of harbour porpoises is a very sophisticated method of observation. The small cetaceans are observed from an airplane flying at a constant height and fixed route consisting of several straight lines (transects). When an animal is sighted, its exact position is noted and the distance from the transect is then measured with an inclinometer This data is analysed with the help of complex statistics, including parameters like the number of sightings, weather conditions during surveys and the length of transects. The density of harbour porpoises (animal / km^2) can then be determined and the total abundance of an area estimated.

This method, the „line transect distance sampling“, has been used by the Research and Technology Centre to investigate the stock and the distribution of harbour porpoises in the German North Sea and in the German / Danish Baltic Sea. The investigation area was divided into seven strata - strata A to D in the North Sea, and strata E to G in the Baltic Sea (fig. 1). Each stratum can be aerially covered in one day. Aerial surveys of the porpoise's distribution and determination of seasonal stock were carried out from 2002 until 2006. Only data that had been attained within 30 days and exhibited a representative number of transects have been included in the determination of the abundance estimates. For stratum A, a representative sampling was not possible for logistic reasons. The abundance estimate for that area in the North Sea was therefore not possible. No statement about harbour porpoise abundance in the winter months can be given because there have been possible only a few flights.

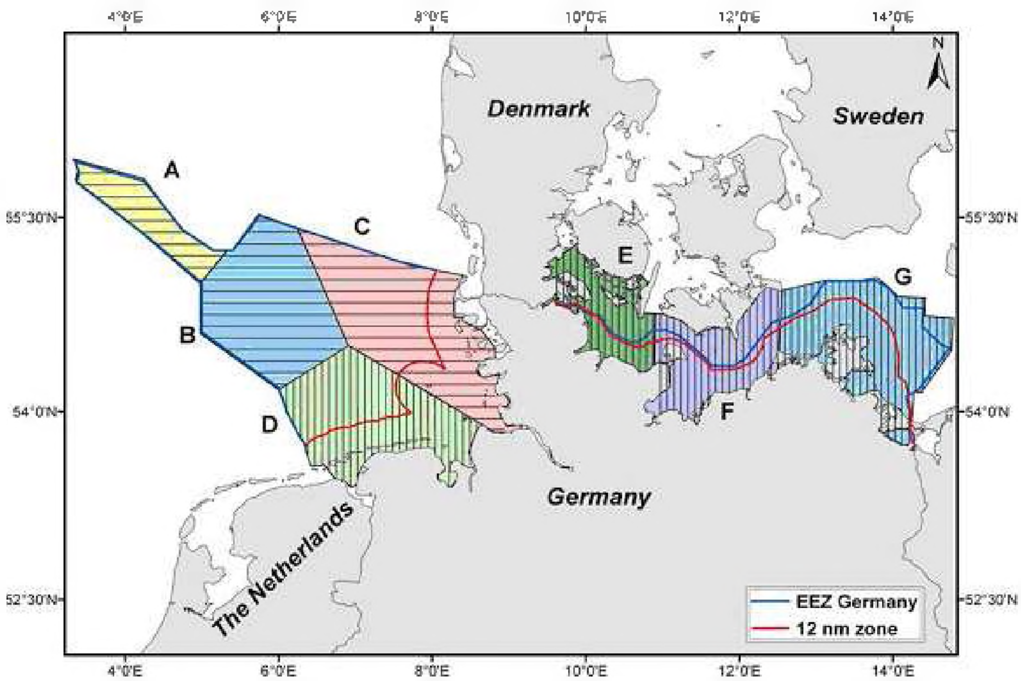

Figure 1: Seven strata, A – G, of the total investigated area of visual observation of harbour porpoises. The black lines show transects of the flights. Every stratum can be observed in one day.

Results

North Sea

Harbour porpoises have been surveyed in the North Sea over the entire year. They were also sighted far away from the coast in area A. The stock fluctuates within a seasonal context but may be compared over the years of the survey. The highest density was calculated for spring / summer with a maximum abundance of about 38,000 (flights in April, May 2005) and about 51,000 harbour porpoises (flights in May, June 2006).

Most animals have been sighted in spring (March - May) in the west of Sylt, in the area of Sylt Outer Reef. Another "hot spot" has been detected in the area of „Borkum Riffgrund". In the summer (June - August), the density of harbour porpoises increased in the area of the Sylt Outer Reef. A gradient of density could be identified from the north to the south (fig. 2). In autumn (September - November), the densities of harbour porpoises decreased. The animals have been more evenly distributed and hot spots have not been identified (GILLES et al. 2005).

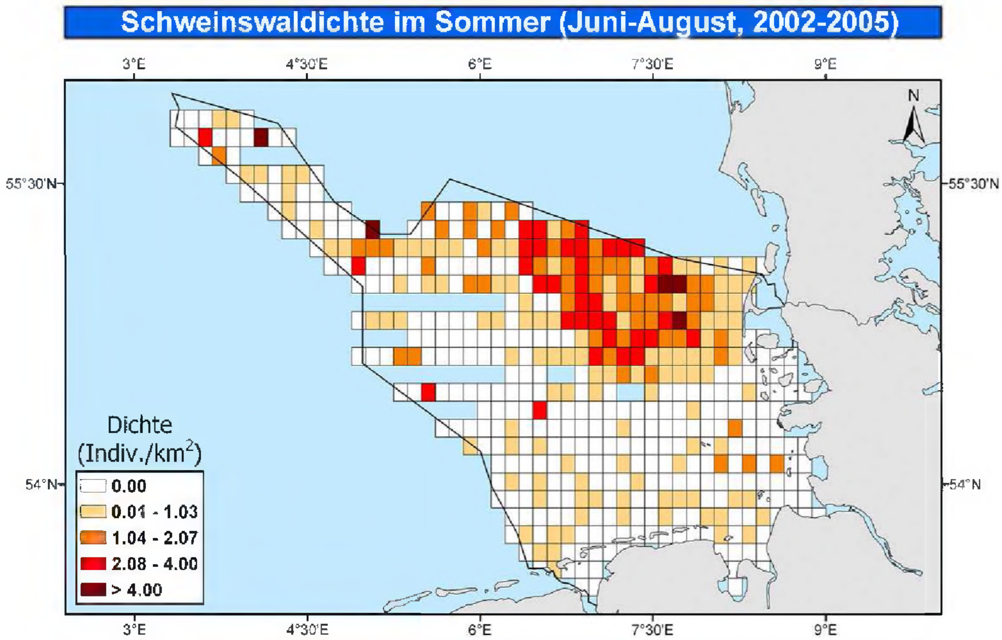

Figure 2: Seasonal densities of harbour porpoises in the German Bight (2002-2005). Grid maps are adjusted for effort. The medium density of porpoises per grid cell (10x10 km) in the summer (June - August) is illustrated. The German EEZ is marked with a black line. Projection: Mercator (from: GILLES et al. 2005).

Baltic Sea

In the German Baltic Sea and adjacent Danish waters, porpoise density was ten times lower than in the German North Sea. In summer of 2003 e.g. an abundance of about 1,700 animals had been registered. A density gradient from west to east had been identified (fig. 3). This tendency was most obvious in September but is not significantly detectable. Large areas, especially section G, have been surveyed without the sighting of a single harbour porpoise (GILLES et al. 2005).

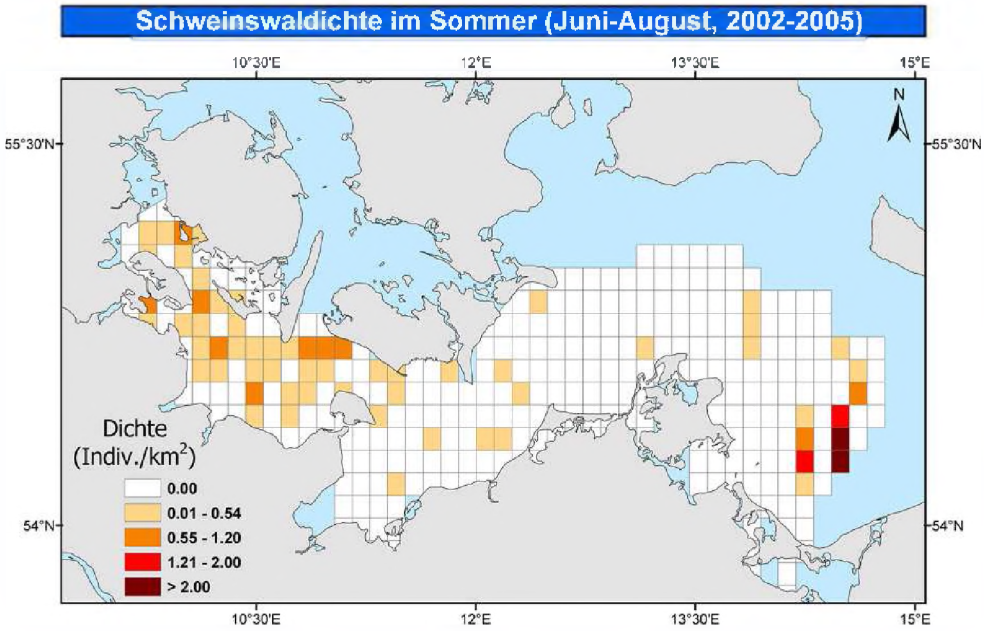

Figure 3: Seasonal densities of harbour porpoises in the Baltic Sea (2002-2005). Grid maps are adjusted for effort. The medium density of porpoises per grid (10x10 km) in the summer (June - August) is illustrated. The German EEZ is marked with a black line. Projection: Mercator. In the summer many unexpected sightings in the east of the investigation area, at the Oderbank were registered. These sightings were not made in every year of the investigation. In July 2002 at the shallow Oderbank an aggregation of 84 harbour porpoises was sighted. In the following years no sightings have been made. (from: GILLES et al. 2005).

Acoustic monitoring

Methods

Acoustic monitoring has proven its worth especially in areas with very low densities of harbour porpoises in the German Baltic Sea. It is not yet possible to estimate the absolute abundance, but detailed knowledge about the seasonal and geographical distribution of the harbour porpoises may be obtained. Echolocation is an active sensory system for harbour porpoises. For them it is as important as the visual sense for humans. It is used for orientation as well as for foraging (VERFUß et al. 2005, VERFUß & SCHNITZLER 2002). With the reflected echoes of high frequency click series the animals produce they can scan their environments. Porpoise detectors (T-PODs) register the point of time and the length of the echolocation clicks. They can be used at gauging stations in the sea over months at a time. Since August of 2002, the German Oceanographic Museum has operated a network of gauging stations in the German Baltic Sea (fig. 4).

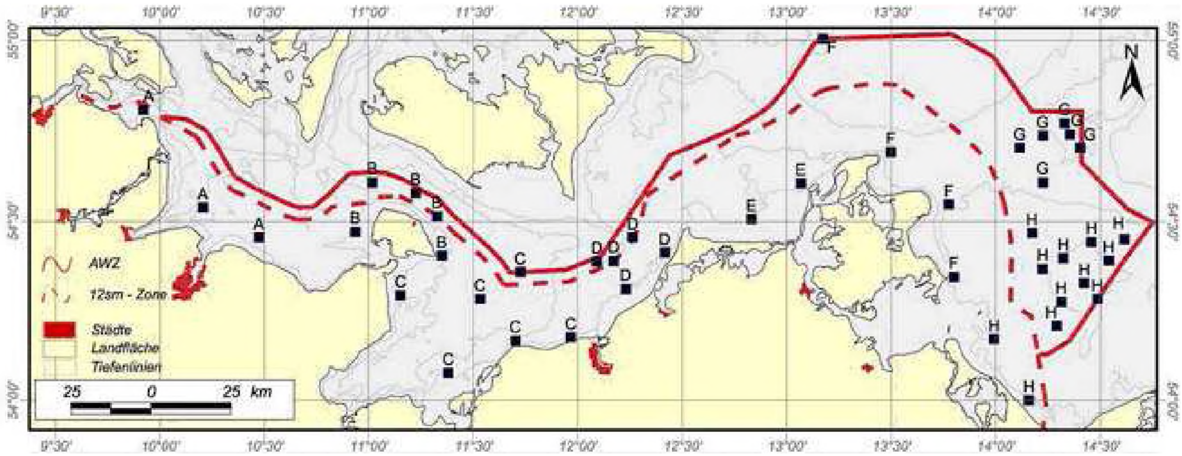

Figure 4: T-POD measuring positions (blue quarters) in the German Baltic Sea. The letters A-H show the grouping of the stations that are merged in the analysis of data in fig. 5 and fig. 6.

At the beginning of the operation there was only a small network of stations: around Fehmarn, in the Kadet channel, near the coast, in the national park in front of Darß, at Kriegersflak, north and east of the island of Rügen, as well as two stations at Oderbank and Adlergrund. The MINOS following project, the MINOS^{plus}[1], facilitated some more gauging stations in Kiel and Mecklenburg Bight. Within the Jastarnia Project, financed by the Federal Agency for Nature Conservation, the Pomeranian Bay was equipped with eleven stations. In the years from 2002 to 2006, the rate of days with porpoise registrations (porpoise-positive days) was analysed in comparison with the total number of investigation days. From 2003 to 2005, the number of hours per day with data recordings of porpoises (porpoise-positive hours per day) were analysed for the stations around Fehmarn and in and around the Kadet channel. The data was regionally and quarterly summarised for the illustration of results in fig. 5. The first quarter contains the months of January through March; the others contain the following months accordingly.

Results

Porpoise-positive days

The data show geographical differences as well as a seasonal variation in the percentage of porpoise-positive days (VERFUß et al. 2007, fig. 5). With the beginning of MINOS^{plus}, measuring began in the first quarter of 2005 in the Kiel Bight. Here, 40% of porpoise-positive days can be observed in the first quarters of 2005 and 2006. In the spring it increases, reaching a maximum peak in the summer. The measuring positions around Fehmarn show similar results, although with more porpoise-positive days. Porpoises were present nearly every day in this area, with up to 100% in the 2nd to 4th quarter. Further east, in the Mecklenburg Bight and in the Kadet channel, the same seasonality can be observed, but with fewer positive days. Fewer porpoise-positive days have been registered off the coast of Darß. The seasonality can be shown here as well. Fewer animals have been registered north east of the island of Rügen. There are only a few yet very regular registrations in the Pomeranian Bay.

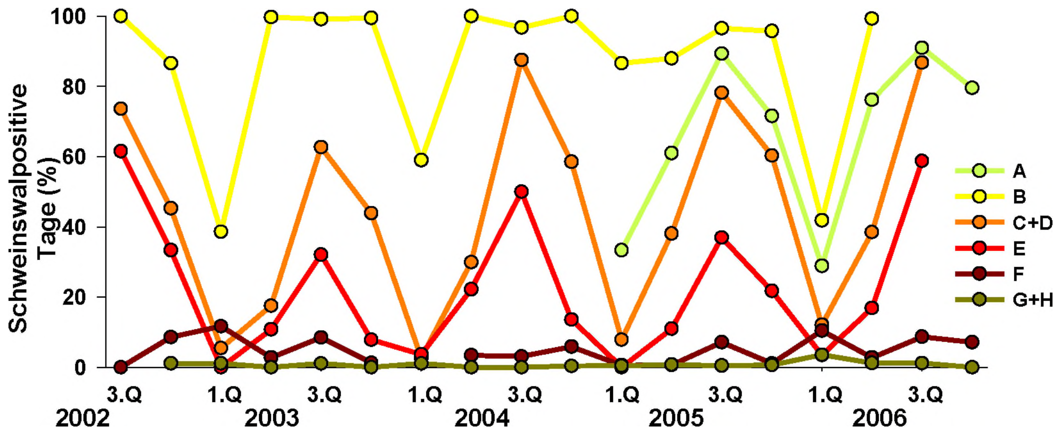

Figure 5: Porpoise-positive days per days of investigation per quarter in the years 2002-2006. The different lines show the merged data of gauging stations grouped A-H in fig. 4.

Porpoise-positive hours

The rate of porpoise-positive hours rises in the 2nd quarter of the first two years of the investigation up to 8 hours per day around Fehmarn. In the summer it decreases to around 5 hours per day and in the autumn it rises again up to more than 8 hours per day. In winter the rate of positive hours decreases rapidly (fig. 6). By contrast the course of porpoise-positive hours in and around the Kadet channel is similar to that of porpoise-positive days.

We assume that the recorded data are caused by the migration of the animals. In the spring porpoises migrate from the Danish Belt Sea into the Fehmarnbelt. In the summer they distribute to the east. In the autumn they slowly adjourn via Fehmarnbelt back into the Belt Sea. The German Baltic Sea is characterised to be an important area for mating, calving and breeding. These important lifecycles occur from spring to autumn. To acquire more experience about the migration of porpoises, the network should be extended up to the north into Danish waters.

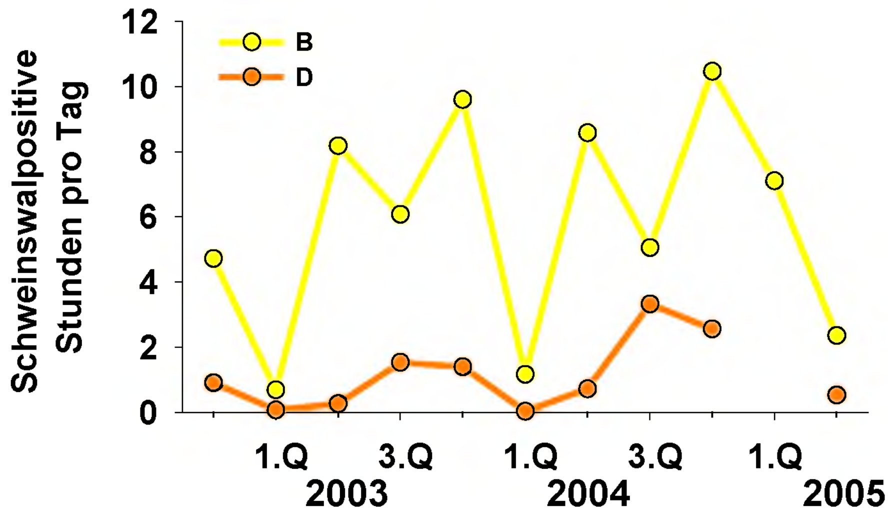

Figure 6: Mean of porpoise-positive hours per day in the quarters of 2003-2005, averaged by the positions in Fehmarnbelt (letter B in fig. 4) and by Kadet channel with the near shore measuring positions (letter D in fig. 4).

Conclusion

The distribution of density of harbour porpoises is liable to seasonal and geographic variation in the North and Baltic Seas. The density in both seas is higher in summer than in winter. Geographical variation can be observed in a north-south gradient in the North Sea and in a west-east gradient in the Baltic Sea. The Sylt Outer Reef has been characterised as a very important area for the small cetaceans. A constant high density of harbour porpoises has been registered there. In contrast, the density in the Baltic Sea is ten times smaller than in the North Sea. The acoustic monitoring proved to be extremely effective with those low density areas. Both methods, the visual and the acoustic monitoring, are very efficient for the investigation of the abundance and habitat use of harbour porpoises in the North and Baltic Seas.

Acknowledgement

The research projects were funded by the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU), including the Investment-in-future programme (ZIP) and by the Federal Agency for Nature Conservation (BfN). We are very grateful for assistance during the flight observations: Sylt Air, Danish Air Survey, FLM Kiel; the observers and navigators: Jörg Adams, Patrik Börjesson, Hauke Giewat, Amaia Gomez de Segura, Iwona Kuklik, Linn Lehnert, Maik Marahrens, Denise Risch, Carsten Rocholl, Ulrika Westerberg, Thorsten Walter, Solvin Zankl. We are also very grateful for the assistance with the acoustic monitoring: The police administration “SEE”, the Coastguard Service, the Federal Border Guard, the Water and Shipping Authorities Stralsund and Lübeck, the Crew of “Seefuchs”, Martin Jabbusch, Ines Baresel, Heiko Charwat, Roger Mundry, Jakob Hansen Rye, Annette Kilian, Marcel Klehm, Kathrin Krügel, Peter Leopold, Dietmar Tode, Nick Tregenza.

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Distribution and behaviour of harbour seals in the German North Sea

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Abstract

Beside Harbour Porpoises and Grey Seals, Harbour Seals are the only resident top-predators in the German Bight. Feeding mainly on fish, they depend on lower levels in the food chain and can also influence them (top-down control). Their amphibious lifestyle makes them an inhabitant of the costal regions along the German North Sea. Depending on the land to haul out, moult and give birth to their young, this is where they were most likely to be threatened by humans.

However, recent plans to built offshore wind farms overlap partially with the seals' offshore foraging grounds and therefore bear considerable influence on the animals' behaviour and distribution.

As we have found out, the seals spend less than 30 % of their time close to land, whereas during the rest of the time, they conduct foraging trips, usually between 4 and 12 days long, which take them 40 km out at sea to water depths mainly between 10 and 20 meters. Even though it is just the outer region of their foraging range, overlapping with the planned offshore wind farms, it nevertheless has potential effects mainly through increasing, wide-ranging noise (especially during the construction phase). A possible positive effect of the wind farms, acting as an artificial reef and therefore attracting fish and seals, could to date not be confirmed during our studies around the Horns Rev wind farm in the Danish North Sea.

Having been diminished up to 60 % by 2 epidemics within the last 20 years, Harbour Seals have recovered rapidly and are not listed as an endangered species. But having to compete more and more for food and space with the increasing numbers of Grey Seals in this area, the impact of a disturbance like the planned offshore wind farms should be assessed properly and considered carefully.

Introduction

There are only three kinds of marine mammals domestic to the waters of the German North Sea, which are particularly worth protecting because of this unique position alone. The species in concern include the grey and harbour seals, both belonging to the earless seal family (Phocidae), and the harbour porpoise, which belongs to the suborder of the odontoceti.

In the food web of the North Sea, these marine mammals assume the highest position as top predators. This means that they are dependent in their nutritional needs on lower members of the food web, but also that they may influence their own composition in the sense of „top-down regulation“ (CARPENTER et al. 1985). They feed primarily on fish. At the same time their position as top predators means that they have no natural enemies, apart from the forces of nature. Only human activity may substantially endanger the existence of these mammals (SEURONT et al. 2005).

While harbour porpoises are fully adapted to aquatic life and live exclusively in marine environments, seals are generally known to lead amphibious lifestyles and bear their pubs on sand banks and coastal locations (ABT 2002). They also spend an essential part of their resting period on land. They are therefore regarded as coastal dwellers. With regard to the planned offshore wind farms, no potential conflicts have been initially expected. Our investigations showed, however, that this might not be entirely true.

Harbour seals and grey seals

Both species of seals were intensively hunted until 1976. By that time, the existence of harbour seals in the entire Wadden Sea had shrunk to approximately 3,600 animals. The population of grey seals, meanwhile, had almost completely disappeared except for just a few individuals between Sylt and Amrum in the German part of the North Sea. Despite two epizootic viral diseases that reduced the population by over 50%, the suspension of hunting combined with subsequent conservation measures have allowed harbour seals a particularly strong recovery, claiming populations of about 20,000 animals at present. (DE JONG et al. 1997; HEATH JØRGENSEN et al. 1988; JENSEN et al. 2002; TOUGAARD et al. 2002-2; REIJNDERS et al. 2006). It is moreover expected that the population is continuing to grow (tab. 1).

Table 1: Characterisation of Native Seals in the North Sea

<u>Harbour Seal (Phoca vitulina vitulina):</u>

Males: 1.80 – 2.00 m long, 100 – 130 (?) kg
Females: smaller and lighter
Resting sites: sand banks in coastal areas and the dunes of Helgoland.
Temporary habitat bound.
Colony size: up to several hundred individuals
Wadden Sea population: approx. 20,000; Tendency: increasing
Breeding Period: end of May – beginning of July

<u>Grey Seal (Halichoerus grypus):</u>

Males: up to 2.30 m long, up to 300 kg
Females: smaller and lighter
Resting sites in Germany: „Knobsänden," the dunes of Helgoland, D-Steert and Norderoog Sand. Relatively habitat bound.
Colony size: varied (20 – 120)
Wadden Sea population: Southern North See 1,700; S.-H. 303 animals.
Tendency: increasing
Breeding Period: December and January

The larger grey seals have considerably increased their population only in the last 10 years. This is especially due to migration from England and the Netherlands, but also because of an increase in local breeding (NATIONALPARKNACHRICHTEN 2007). One can expect an even larger annual growth rate here than that of harbour seals.

Both seals utilize the same resting sites and probably seek out the same food sources, leading to an eventual competition between the species. In the long-term, it is quite possible that the grey seal will achieve the upper hand in the North Sea, and that the harbour seal will end up playing a smaller role in the Wadden Sea. In the near future, however, the number of resting sites might be sufficient to support both seal species. Regarding feeding, it is more difficult to appraise the situation, as we know next to nothing about the under water behaviour of grey seals.

No known competition exists between harbour seals and grey seals with regard to breeding and moulting times. Both periods take place in the winter for grey seals and in the summer for harbour seals. The most important seasonal cycles of the harbour seal are illustrated below in fig. 1.

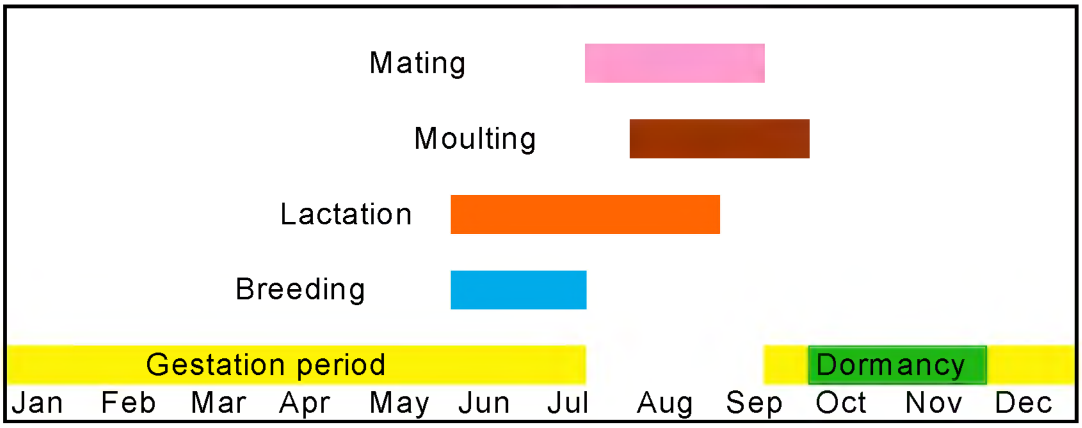

Figure 1: Harbour Seal Calendar

For several years it has been observed that the recorded biorhythms until now have shifted to earlier time periods in the year. The reasons for this are complex, but might be indirectly connected with rising temperatures at sea.

Pups are born onshore. The lactation period of the pups, which usually lasts between three to five weeks, also takes place exclusively near the coast, in order to ensure the resting needs of the young animals. The pairing season then follows (BOWEN et al.1999). Mating takes place in the water, but predominantly in close proximity of resting sites. Then follows the annual moulting period of the older animals, which is likewise connected with higher resting needs.

From the beginning of the birthing period until the end of the moulting season, harbour seals seem to linger predominantly around the coast. The evaluation of existing data must show however, to what extent offshore prey known to us are reduced during this time. Unfortunately the data situation here is somewhat weak. If deep-water prey are actually threatened in the summer half-year, the timing of construction activities for offshore wind farms could be of concern with respect to the conservation and protection of harbour seals.

Harbour seals are basically opportunistic foragers who feed above all on prey that are most easily captured (HALL et al. 1998; TOLLIT et al. 1998). Analyses of the stomach and intestines have furthermore proven that the free-swimming seals eat predominantly bottom dwelling fish, with a substantial preference for small plaice fish and other flat fish (fig. 2). Although the food spectrum varies according to seasonal supply, the results of our investigations show that almost exclusively benthic food is consumed over the whole year.

In the zoo, harbour seals are fed a diet of almost exclusively herring, whereby adult animals receive between 3 and 5 kg of fish a day. Compared with a fatty provision of herring, the daily feeding on the open sea is relatively leaner. Because of this, and combined with the large amount of energy expenditure associated with the activities of foraging in open sea, the daily need for sustenance is probably much higher in the wild than in captivity.

Based on their larger body size, the nutritional requirements of grey seals are to be seen as higher than that of harbour seals. The size of the individual prey of the grey seals is likewise expected to be larger than that of the harbour seals, i.e. they may eat for example somewhat larger flat fish. There is albeit little concrete information to confirm this.

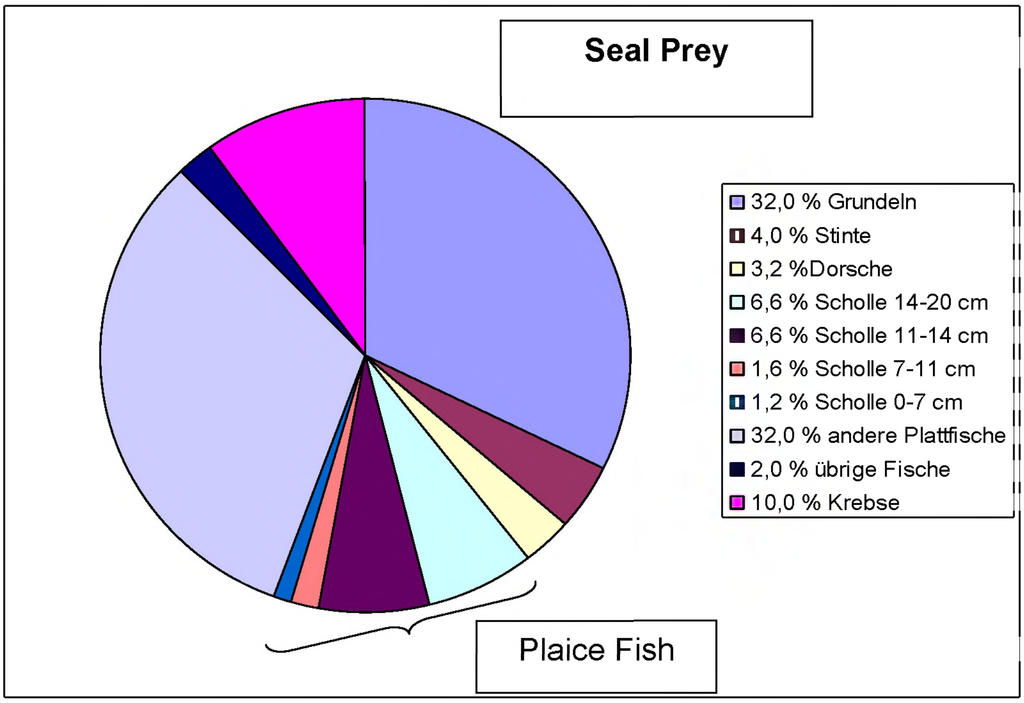

Figure 2: Break down of harbour seal prey over one year, determined by the analysis of food remainders in the digestive tract of dead animals.

Problem definition and research objectives

Due to conservation measures mentioned above, the existing population of harbour seals is currently secure and continues to grow. To what extent and rate the stronger grey seals will displace the harbour seals, can only be speculated at this time. If however, the construction and operation of offshore wind energy facilities should negatively affect the lives of harbour seals, then this process of displacement may occur sooner and more severely. To what extent the effects of offshore wind development could have on grey seals, has not yet been examined. Based on past research, the definition of the problem is outlined below in fig. 3.

In order to clarify the above-mentioned problem, the following questions should be given priority:

- Which activities do the harbour seals exhibit at sea?
- How far does the harbour seal's spatial realm of action extend?
- Are there seasonal, age or gender specific differences in the activities or realm of action?
- How is the ecological compatibility of offshore wind farms assessed?

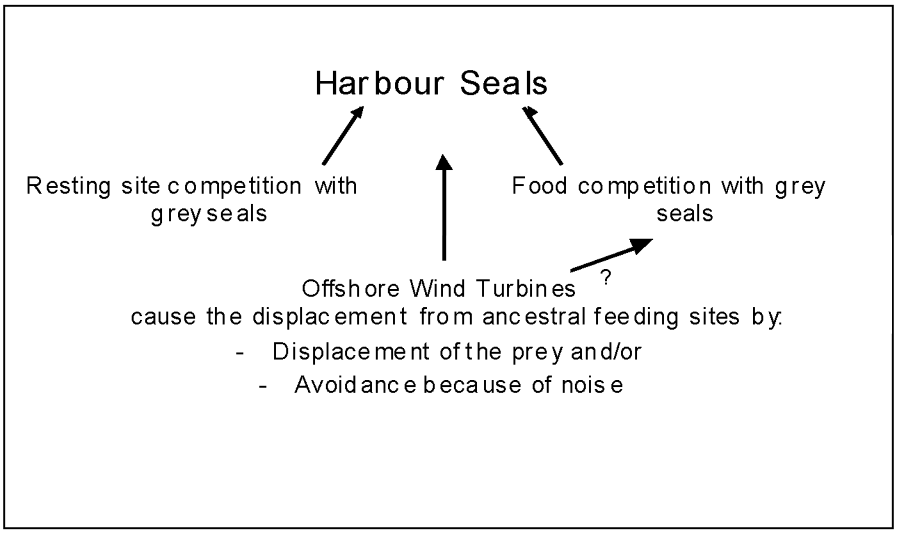

Figure 3: Outlined diagram of problem definition – grey seals and offshore wind energy facilities. The arrows are not to be quantitatively understood, but rather point out possible relationships.

An additional side effect of the study has been the opportunity to answer some open questions about the biology and inventory of harbour seals. Some questions include, for example, whether the correction factor in the case of survey flights must possibly be changed due to gained insights about the water-borne life of harbour seals, or for example, how the energy balance of harbour seals stands and whether this reflects how much prey the seals actually consume.

Methods

Until some time ago, it was not possible to track harbour seals after they had hauled out of their resting areas to go foraging for food, as direct observation is impossible. In order to obtain information nevertheless, small radio devices were first fastened onto the heads of animals. However, because of the limited transmission range and the influence of inclement weather conditions, such devices could only transmit information about the activities of animals near the coast. (RIES et al. 1997; BLACK 1997). The replacement by satellite transmission devices increased the tracking possibilities (WHITE et al. 2002), but still produced only very limited information about the underwater activities of harbour seals. In principle, radio transmission is only possible when the antenna rises up out of the water, i.e. when the seal emerges, which is problematic because the animals spend most of their time at sea under water.

For this reason we developed a ten-channel data logging device in co-operation with the company Driesen and Kern GmbH (Bad Bramstedt, Germany). This device also functions under water and has the following sensor channels:

- Channel 1 – 3 three-dimensional compass
- Channel 4 dive depth via pressure sensor
- Channel 5 swim speed via pressure difference
- Channel 6 body orientation (belly or back stroke)
- Channel 7 water temperature
- Channel 8 roll
- Channel 9 pitch

- Channel 10 light intensity

The data logger electively records measured values from all ten sensors every 5 to 15 seconds and stores these on a chip with a memory capacity of 32 MB. In this way the activities of a harbour seal can be continuously recorded over approx. three months.

Although a wireless data transfer is not possible because of large file sizes, the data loggers were additionally equipped with a satellite transmitter. This transmits the seal's haul-out and return positions during a foraging trip, i.e. when the seal leaves the sand bank and when it returns again. The position of the unit when it is washed ashore after separation is also indicated. Because the equipment is mounted on the back of the animal, no transmission is possible when the seal is at sea, as the antenna is at least partly concealed under water.

Data loggers, satellite transmitters and additional accessories are packed into a hydrodynamic buoyant hull, so that the entire unit drifts in the water after separation and is eventually washed ashore after some time by the parallel coastal current in Schleswig-Holstein. In order to retrieve the stored data, the devices must be found again. If no technical damage is present, the devices may be re-used after replacing the batteries.

Over 70% of the devices were found again. Some were found by chance by beach walkers, and others by site-specific searches thanks more or less to the detection function of the satellite transmitter. However, not all retrieved devices were useful to the study because of technical defects such as water damage or premature separation from the seal. Of the altogether 73 devices deployed in the $\text{MINOS}_{\text{plus}}$ research project, 53 logger units were retrieved so far. Of it these data records, 36 devices proved to be fully or at least partly useful for evaluation.

With the help of the compass and speed data, the routes of harbour seals may be computed via a „dead reckoning system". This is unproblematic at the horizontal level, but difficulties occur in the computation of three-dimensional areas. Besides drift, the roll and pitch of vertical movements and dives of the seals must also be considered. For a long time the available software proved to be insufficient. Only recently was a solution possible as a result of a correction factor by Professor Koch of the Institute for Computer Sciences at the University of Kiel. The Jensen Software Company in Laboe has integrated this new development, and initial tests have already proved to be successful.

Furthermore, the data logger records very precise information about submerged depths and respective lighting conditions, but less exact information about water temperatures.

In order to equip the harbour seals with data loggers, the animals must first be captured. This is a relatively personnel-intensive, logistically time consuming and weather and tide-dependent operation. For example, six attempts to capture seals last autumn failed due to storms and floods.

Successful capture occurred at three locations: on the dune just outside Helgoland, on the Lorenzenplate, which is a sand bank west of the peninsula of Eiderstedt, and on the Danish island of Rømø, in whose proximity is located the only Danish wind farm comparable to the planned German wind farms.

The goal of each operation was to catch in each case at least eight harbour seals. This was however only possible four times. Thus for example on Helgoland, the harbour seals were scared away several times by tourists, so that despite intensive efforts, only two, three or five animals could be captured. Due to the inferior quality of the Danish netting gear, only a few harbour seals went into the net several times at Rømø.

It is also important by the capture of harbour seals to minimize potential stress on the animals as much as possible. Thus in principle, young animals or those who exhibit stress signals are immediately released, without being equipped with devices.

It is also highly important that impediment or injury to animals by the devices is kept to an absolute minimum. The devices were therefore designed with a streamlined shape, attached to a shoe-like mounting of neoprene, and depending on the size of the unit glued at only five and/or seven points to the animals' fur. The device was tested on trained animals at the harbour seal station in Friedrichskoog before it was applied in the wild.

Chance observations by others and us showed that the animals equipped by us behaved completely normally. The normal out going condition of the animals was the most substantial qualification for the gathering of all other data about the behaviour of harbour seals.

Two types of devices were used. Smaller, lighter equipment without electronic replacement mechanisms were used in the summer, since the equipment detached freely on its own during the annual moult in August. In the autumn and winter, the devices were equipped with a pre-programmable replacement mechanism, since moulting was not expected to occur after the 3-month long recording period. These devices were therefore somewhat larger and heavier.

The logger unit has a weight of approx. 600 g. The weight of the seals was on average 75 kg, which means that the devices in total were less than 1 % of body weight on land, whereas at sea they were slightly positively buoyant or weightless.

Essential is also the positioning of the equipment, in order to avoid handicapping the animal. The attachment of the device at the centre of the back proved to be hydrodynamically favourable. Here the skin is only loosely attached to the body and is underlaid with a thick layer of fatty tissue. The animal is therefore not exposed to unnecessary tensions caused by the equipment.

As already mentioned however, the undesirable effect of the device's attachment position on the seal's back is that the antenna hardly appears when the animal emerges, since the animal's body orientation by diving and coming up for air is practically vertical in the water. Only rarely do they swim or drift on the water's surface in such a way that the back is freely exposed, allowing the device to transmit a signal. Exact location data are therefore only transmitted when the animals are resting ashore.

Results

Active biorhythms

After re-locating the devices, the stored data is selectively read by special software. An initial overview of the data is thus available for each of the individual channels. In order to discern the details, these must then be transformed and spread.

Two examples of raw data sets before their transformation processing are illustrated in figs. 4 and 5. The data sets come from two harbour seals, which were equipped with devices at the same location, the Lorenzenplate sand bank, but at different times in the year. Fig. 4 shows recordings from August 25 (directly after moulting) to October 10. The second line shows diving activities, including submerged depths. They indicate foraging routes of 4 - 6 days in duration, to approx. 20m depth. These are interrupted only by brief resting periods in shallow water. The animal concerned is a somewhat smaller 8-year-old female, who was rescued as an abandoned seal pup and brought up in the Friedrichskoog harbour seal station in 1996.

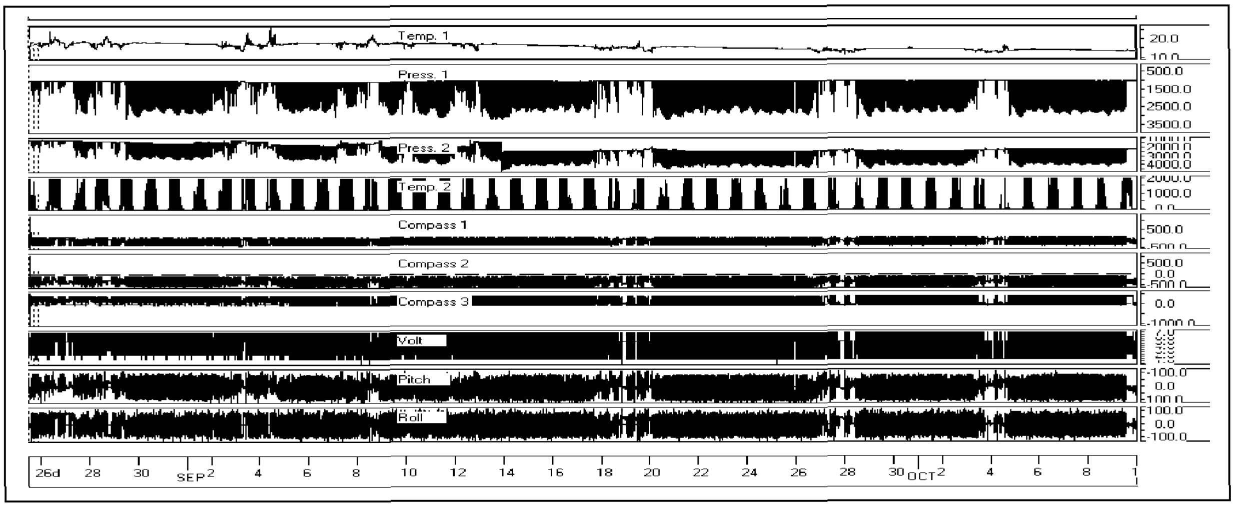

Figure 4: Recording of the activities of harbour seal LP 08.04-3. Pressure is indicated on the x-axis in millibars. For orientation it is said that 3000 mbars correspond to a depth of approximately 20m. The recording took place from August 26 to October 9, 2004.

The activities of a female harbour seal are illustrated in fig. 5. The pregnant seal was equipped with a logger device on April 12 and tracked until June 25. Line 3 shows that the seal undertook foraging trips of up to 20m depths by 4 June. Of remarkable interest is the length of these foraging trips, some of which lasted up to 15 days. An abrupt change in diving behaviour took place after June 4. From then on, up to the end of the recording, the harbour seal spent her time exclusively in shallow water. It is assumed that the birth of the pup took place on June 5, followed by the lactation period. During this whole time, the mother seal spent all of her time in the shallow waters along the sand banks.

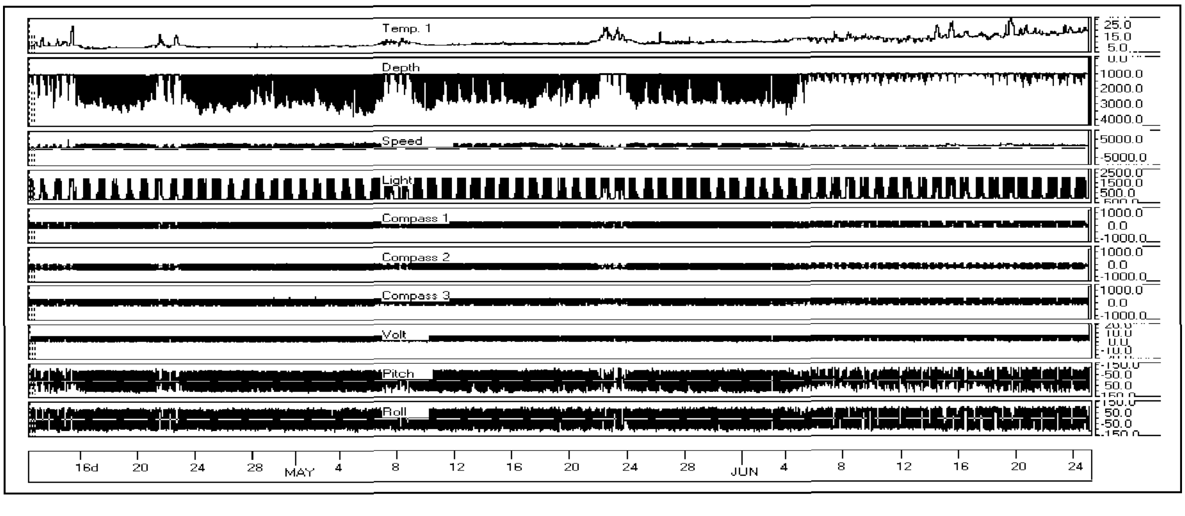

Figure 5: Recording of the activities of the female harbour seal LP 04.05.-2. The animal was already pregnant when she was equipped.

Similar summer behaviour was shown by altogether five animals (2 ♀ and 3 ♂). Three further animals seem to have behaved in the same manner, but a more exact analysis is still required. Obviously not all animals behave in exactly the same way. One divergent example was that of a female seal, probably not pregnant at the time, which carried out far reaching foraging trips well into the cooler season. The trend of not undertaking long and deep foraging routes in May and June is not however clearly evident or only limited to females. A reinforcement of the database is desired here, in which further animals should be equipped at the beginning of spring.

The behaviour mentioned here however, probably only applies to animals on the Lorenzenplate and similarly situated resting areas. In contrast, harbour seals from the dune of Helgoland seem to predominantly undertake daily trips at least in the summer time. After the annual moult until well into December, the seals undertake foraging trips lasting up to several days. Whether they are still stationed in Helgoland then or have migrated to the mainland coast is still to be verified with help of available satellite data.

Furthermore, the animals from Rømø also exhibited no seasonal trends. It is remarkable here however, that the foraging trips of predominantly only 4 days are clearly shorter in duration than those of the Lorenzenplate seals. The location possibly plays a role here, which makes it possible for the animals to reach preferred deep-water food sources faster. It should also be considered that so far no female seals were captured or equipped by us on the island of Rømø. The behaviour exhibited could therefore represent an exclusive group of bachelors with possibly different habits.

The extent and calibration of diving profiles provide fundamental realizations about the behaviour and approximate inhabitation of harbour seals (fig. 6). From the analysis of down tilt data, it is shown that that the animals usually dive down very steeply, display a bottom phase of approx. 2 - 5 minutes, and then steeply re-emerge for oxygen before repeating the process again. Such dives are known as „U-dives“. The seals usually dive right down to the seabed, where they hunt and capture fish. Such dives can follow consecutively for three hour long periods, only then followed by resting periods of 10 - 30 minutes, in which the animals only dive up to a maximum depth of 5 m.

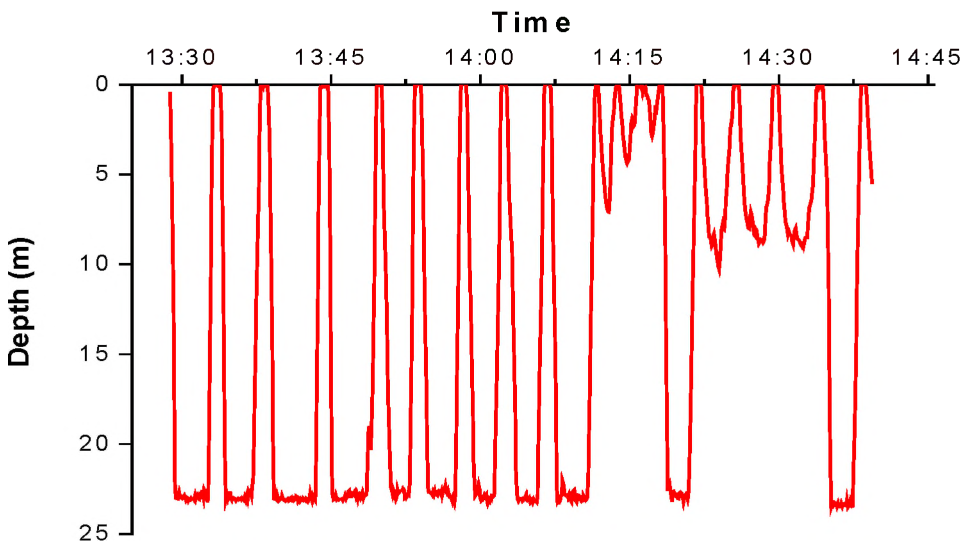

Figure 6: Detail of a diving profile with U-dives, including a bottom phase where the harbour seal swims along the seabed at a depth of 23 m for 2 - 5 min. In addition some V-dives can be seen, in which a maximum depth of 10 m is reached and no bottom phase is exhibited.

In addition to the U-dives, there are so-called V-dives (fig.6), which are more rarely and do not usually reach the seabed. These dives could possibly represent search or scouting dives in the hunt for food.

Foraging Behaviour

The foraging routes of harbour seals can be determined with the help of dead reckoning systems. The example in fig. 7 shows the typical path of a foraging route, which begins and ends on the Lorenzenplate sand bank. Because the animals usually dive down to the seabed, a bottom profile is also recorded, giving the tour a three-dimensional component. First the harbour seal swims to a large extent straight ahead, until it reaches an area, where it constantly swims back and forth. Here it seeks out its prey, which can take several days. Subsequently, it returns via a relatively straight route to its resting site.

Both on the way there, in the destination area and on the return trip the seal nearly always dives down to the depth of the seabed.

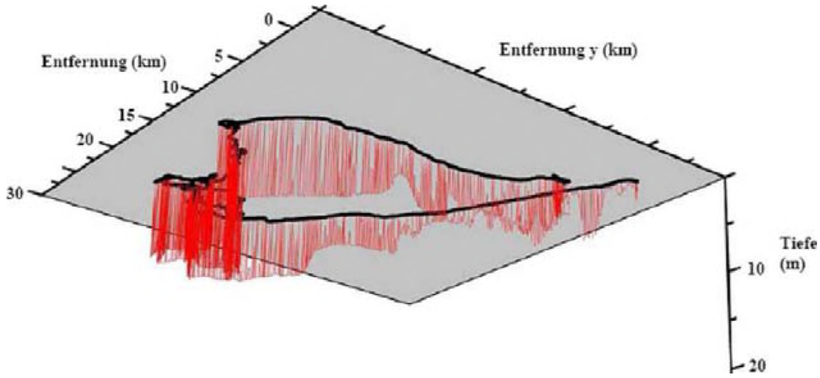

Figure 7: Swimming route (black) of a harbour seal after leaving the sand bank with diving profile (red). With continuous dives down to the seabed, even in the shallow Wadden Sea, the harbour seal swims into a 20m deep destination area to forage for food for several days, before returning again to its resting site.

If one regards the routes analysed thus far, which admittedly must be revised due to above mentioned software difficulties, then all foraging routes originating from the Lorenzenplate and Rømø locations lead into deeper waters offshore (fig. 8) (LIEBSCH 2006; NØRGAARD 1996). That means that the harbour seals for the most part do not feed themselves in the Wadden Sea. There is a clear distinction between „bedrooms“ and „dining-rooms.“ The diagram also shows that the harbour seals do not generally swim into the range of the planned offshore wind farms, but rather prefer the diving zone of 10 - 20m just before the planned wind farms. The registered submerged depths confirm these findings.

Harbour seals do not seem to directly avoid the already operational wind farm Horns Rev, but passed through the area without stopping to forage for food there. The exact data must however be re-analysed with the corrected routing software to confirm if this conclusion truly reflects actual behaviour.

By a general survey of the situation, it must also be confirmed that such examined resting areas are indeed harbour seal resting areas, regarded as orientation points by the harbour seals. The grey seals, with their substantially larger spatial range of activity, must also be considered here.

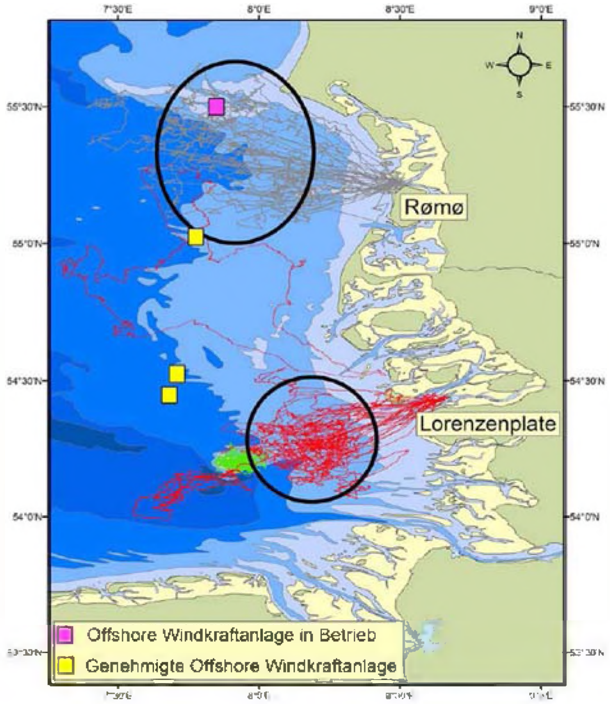

Figure 8: Foraging routes of harbour seals from the resting areas Lorenzenplate (red), Rømø (brown) and Helgoland (green).

In addition to a growing colony of grey seals, harbour seals in changing numbers are to be found all year round on the island of Helgoland. In contrary to the grey seals, which breed here in December and January, the harbour seals are not known to bear their pups on Helgoland. The reason for this might be the disturbing presence of tourists in the summer. With the help of the satellite transmitters, we could show that the female animals retreat to the East and North Frisian Islands briefly before giving birth to their pups there.

The Helgoland harbour seals also behave differently in their foraging route behaviour than seals from the mainland coast. Our past investigations showed that the foraging trips take up to 24 hours at the most, before the animals return to the Helgoland dunes. The diving profiles correspond however to those of the mainland animals, i.e. they constantly include bottom dives, implying that they too seek out their prey on or near the seabed level. The food offering around Helgoland is apparently quite plentiful.

Because of the strongly increasing existence of grey seals (32 young animals in the winter 2006/2007), Helgoland also proves to be an excellent location to examine the possible competition between grey seals and harbour seals, and for the first time to study more closely the behaviour of grey seals in the German Bight. It is therefore also possible to draw conclusions about possible disturbances from offshore wind energy turbines.

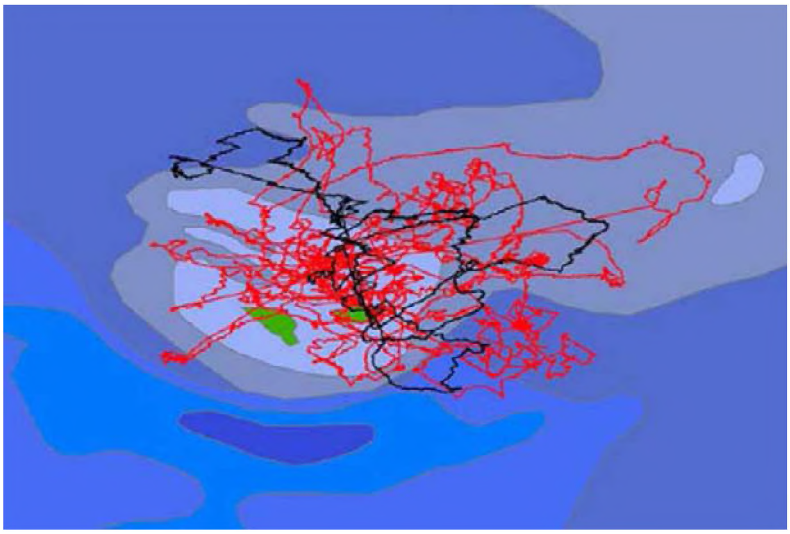

Figure 9: Foraging routes of Helgoland harbour seals. Females: red, males: black

Conclusions

Although the specified findings are based on past evaluations and must be backed up by further data analyses, they point to clear behavioural trends. The summer resting period, for example, amounts to probably more than 30% of the time onshore, and varies from location to location. Additionally, most harbour seals from coastal locations do not seem to undertake distant foraging routes during this time. In contrast, resting needs are substantially smaller after the annual moult and during the winter. This theory is not new, but may however be finally proven for the first time thanks to our data logging technology.

After the annual moult, the harbour seals probably embark on their search for feeding locations, giving preference to offshore locations of about 10 to 20 m depth outside of the Wadden Sea. These are located at the outer edge of the planned wind farms. Whether and to what extent a forced displacement of the seals as a result in particular of the construction noise entailed with the development of the wind farms, must still be examined.

Our past test results on Rømø, which agree with those of our Danish colleagues (TOUGAARD et al. 2003), conclude that the harbour seals were not displaced by the operation of the wind turbines, but were also not particularly attracted to the area as a foraging location resulting from the changed substrate. The wind farm of Horns Rev was however developed in a very shallow area, which possibly never represented an attractive foraging area for the seals.

The past results point to seasonal differences in the behaviour of harbour seals. An exact data analysis must be carried out to prove or rule out sexual or age conditioned differences (THOMPSON et al. 1998). The data coverage for such an appropriate analysis is still very weak however.

Based on this and other addressed points, objectives for future research could be summarised as follows:

- Confirmation of the data pool until now;
- Further investigation of seasonal, age-based and sexual differences;
- Clarifying the acoustic dangers caused by the construction and operation of offshore wind farms;

- Use of the area around East Frisia;
- Further research on grey seals, investigation of their competition with harbour seals as well as their possible endangerment by offshore wind energy turbines.

Acknowledgements

We would especially like to thank BMU/PTJ – Jülich for their sponsorship and endorsement of this project. Further thanks apply in particular to the ALR - Husum for the supply of ships and crew for the harbour seal capture on the Lorenzenplate, to the NPA - SH in Tönning, to the company Driesen and Kern (Bad Bramstedt), to the Friedrichskoog Harbour Seal Station, to Svend and Jakob Tougaard, Thyge Jensen and other Danish colleagues for their support with the harbour seal capture on Rømø, to the FTZ - West Coast in Büsum, as well as to Mrs. Mandy Kierspel and the harbour seal hunters Mr. Rolf Blädel and Dieter Siemens on Helgoland. We would also like to thank the many volunteers with the capture of the harbour seals and all of the beach visitors who retrieved the data loggers.

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Natura 2000-protected areas in the German Exclusive Economic Zone (EEZ)

Dr. Elsa Nickel, Annika Wallaschek, Federal Ministry for the Environment, Nature Conservation and Nuclear Safety

Will be delivered in addition.

News about the approval procedure for offshore wind farms in the German EEZ (?)

Summary of the presentation by Christian Dahlke – Federal Maritime and Hydrographic Agency
summarized by Leena Morkel – TU Berlin
Translation by Leena Morkel, Alexandra Toland – TU Berlin

Approval procedure of offshore wind farms

The Federal Maritime and Hydrographic Agency (BSH) carries out the application procedure for wind farms and their grid connection in the German Exclusive Economic Zone (EEZ). The Marine Facilities Ordinance is the legal basis for licences of wind farms in the EEZ. Its spatial scope is bordered by the 12 nautical mile limit.

The approval is given within a „bound decision“. Therefore no latitude of judgement exists, but rather a legitimate claim for licensing. Furthermore, no effect of exists for licensing.

According to § 3 SeeAnlV, an approval can be denied in cases of:

- Impairment of the safety and efficiency of navigation.
- Endangerment of the marine environment and bird migration.

According to SeeAnlV, the following aspects cannot influence the refusal or decision:

- National defence
- Fishery
- Natural resources
- Tourism
- Inefficiency
- Lack of economic power
- Energy requirements and grid integration.

Conclusion of the previous approval procedure

The previous approval procedure can generally be classified as accepted. This is caused by the provision of broad information to all involved parties (authorities, organizations, institutions, organisations of interested parties and the public).

Because of its step-by-step approach, the approval procedure is predictable. This means that the applicant can clearly appraise risks up until the time of significant investments (= conference of the approval).

State of the proceedings

40 applications have been handed in until February 2007. These include the plans for 34 wind farms in the North Sea and 6 offshore wind farms in the Baltic Sea. Furthermore, 16 applications for cables have been processed (14 in the North Sea and 2 in the Baltic Sea).

18 offshore wind farms in the German EEZ have been approved so far. 15 licences have been granted in the North Sea and 3 wind farms have been approved in the Baltic Sea (BSH 2007, in the Internet). Two applications for offshore wind farms in the Baltic Sea have been refused. These are the plans for the wind farms „Adlergrund“ and „Pommersche Bucht“. The Higher Administrative Court dismissed several claims.

New developments in the approval procedure

In the view of the authorising agency, an enhanced appreciation of reality for the feasibility of plans for offshore wind farms exists. This can especially be seen in the financing and the technical conception of the projects.

A tendency of the access of the „industry“ is emerging because initiatives, like civil wind farms and planners, must have realized that a financing is not possible because of the distance of the wind farms to the coast. This means that the big companies got involved in most of the project proposals and that actual developments, which have already been licensed, are offered to financially strong investors.

The involvement of more legal aspects has caused additional conflicts about different questions and increased the use of legal “remedies”.

The pressure of competition in the area of offshore wind is rising.

As a basis for the creation of legal certainty, standards have been defined.

As a consequence of the development of wind farm projects, the question of a structure of regional space came up. Therefore approaches for an overall analysis of the natural assets and for a regional plan are currently being worked on.

General standards

Geotechnical site investigation standard

The geotechnical site investigation standard was published by BSH. It is legal since August 1, 2003. The paper includes minimum standards for the foundation of wind energy turbines. The standard should guarantee the stability and the security of the turbines.

Construction standard

The construction standard was published in June 2007. It includes instructions for the technical design of offshore wind farms including secondary equipment. It also contains a systematic survey of each element and of required technical certificates for the whole project.

Instructions on risk analysis

If a collision liability from 100 years for a planned wind farm is estimated, it is licensable from this point of view.

Concept for protection and safety (SchuSiKo)

The concept for protection and safety is currently in progress. It contains information about the design and operation of the project, as:

- Equipment, navigation lights, AIS,…
- Scheduling including waste management, operation.
- Emergency concept.

Standards for the environmental impact assessment (StUK)

The StUK was compiled for the assessment of impacts on the marine environment caused by offshore wind energy turbines. Since February 2007 a third version (2nd revision) exists. The StUK contains information about basic assessment and monitoring.

From the handling of projects to the structuring of space

For spatial assessment, it is essential to interweave research and monitoring. The offshore test site can be used for both, monitoring and accompanying research. Furthermore, an overall spatial observation is necessary.

Coordination of interests through spatial planning

Spatial planning should afford a reconciliation of interests of different demands of usage for the EEZ. This should be carried out in the following way:

- Spatial division of conflicting uses, where possible.
- Priority for special uses according to the requirements of the United Nations Convention on the Law of the Sea (SRÜ), e.g. for shipping routes.
- Definition of objectives / principles for the minimization of conflicts.

Steps on the way to spatial planning

Firstly according to § 3a SeeAnlV, especially suitable areas for establishing wind energy turbines have been established. The background for this was the “Strategy of the Federal Government for the Wind Energy Use on Sea” within the “Strategy for a Sustainable Development” (2002). By the end of 2005, three especially suitable areas had been appointed (Nördlich Borkum, Kriegers Flak, Westlich Adlergrund). The aim of the establishment of especially suitable areas was a systematic development of the use of offshore wind energy within the choice of location. The especially suitable areas will be taken up in future spatial plans as priority areas.

Starting points for the development of spatial planning in the EEZ

Only a little experience with marine spatial planning actually exists. There are still knowledge gaps for potentially important parameters. The spatial plan should contain existing and approved utilizations. Shipping routes should provide a basic structure for spatial planning.

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Strategic environmental assessment for the utilization of offshore wind energy

Prof. Dr. Dr. h. c. (GTU Tiflis) Thomas Schomerus, apl. Prof. Dr. Ing. habil. Karsten Runge, Dr. Georg Nehls[2]

Translation: Alexandra Toland, Leena Morkel, TU Berlin

Abstract

The Strategic Environmental Assessment (SEA), based on the Directive from 27 June 2001 (2001/42/EC) was transferred into German law by the Act of 26. 5. 2005. It offers an appropriate instrument for securing standards of environmental protection at an early stage, covering wide areas of offshore wind energy-usage in the German Exclusive Economic Zone (EEZ). In cooperation with the "Projektträger Jülich", the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety have sponsored a research project concerning important aspects of SEA in the German EEZ. From the various stages of SEA-procedure, the article focuses on the environmental report and monitoring stage. The information in the SEA-environmental report differs from that provided by the developer in the Environmental Impact Assessment (EIA). Aspects in which this occurs are for instance the institution in charge of the report, the assessment of reasonable alternatives, dimensions of time and space and the treatment of knowledge gaps. Should the German Federal Government's offshore wind energy strategy be put into effect, then the CO_2-output of the German power generating industry would be reduced by 14%. This positive effect on climate protection must be taken into consideration. Monitoring is another important issue of SEA. Before embarking on this process, however, a number of issues must be clarified, i. e. the aim of the monitoring process, financial responsibility or follow-up procedure in the case of deviations from those environmental impacts initially envisioned. Since positive effects on the environment must also be considered, SEA is not an instrument for preventing offshore wind energy usage but rather supporting the planning process.

1. Introduction

The Strategic Environmental Assessment - short: SEA (SUP in Germany) - is an instrument with which nature and environmental protection standards may be secured at a regional level and an early stage in the planning process. For the use of offshore wind power in the North and Baltic Seas, and in particular in the German Exclusive Economic Zone (EEZ), the SEA offers an opportunity for multilateral planning, including many different aspects which are not covered by current licensing procedures for individual wind parks.

These questions were examined in the research project „Strategic Environmental Assessment and Strategic Environmental Monitoring for Offshore Wind Energy Parks" that was funded by the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety and by „Projektträger Jülich". In the research project carried out by OECOS Hamburg, Bioconsult SH and the University of Lüneburg, the interdisciplinary fields of planning, biology and law were linked with one another from the beginning stages of research. In this way it was ensured that the expertise from one discipline could be directly integrated into the work of the other disciplines. The project was carried out in three phases, in which the first two - „Fundamentals of Ecological Planning" (SCHOMERUS/RUNGE/NEHLS et.

[2] The authors would like to thank Mr. Wiss. Mitarb. Dipl. Umweltwiss. MARCUS STEFFENS for assisstance in the compilation of this article.

al., 2006, 1 ff) and „Effects and Monitoring at the Regional Scale“[3] - have already been completed. The third stage of the project that is recently applied for is to include an international comparison and calibration of the SEA for the utilization of offshore wind energy.

Though it is not possible to illuminate the entire breadth and depth of the project's contents here, the goal of this journal contribution is it to present some of the most important results. After an introduction to the fundamentals of SEA (2.) a few aspects will be discussed in detail i.e. the environmental report for the offshore wind energy use with its relevant differences between the Environmental Impact Assessment (EIA; in German UVP) and the SEA, and the inclusion of climate protection into the SEA (3.). The conclusion contains general remarks on monitoring (4.), as well as a summary of results (5.).

2. Introduction to the fundamentals of SEA

The SEA is a relatively new spatial planning instrument (SCHINK, 2005, 143 ff. and SCHOMERUS/BUSSE 2005, 398). After considerable discussion in the year 2001, the European Commission SEA proposal (DIRECTIVE 2001/42/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 27 June 2001 on the assessment of the effects of certain plans and programmes on the environment) was issued into law. The integration into national legislation in Germany first occurred on a specialized legal level via the so-called „Law for Integration of European Legislation in Building and Construction“ in 2004, in which legislators managed to hold the conversion deadline of 21.7.2004 (Law for Integration of European Legislation in Building and Construction 24.6.2004, BGBl. 1359 ff. The newly integrated § 18 a of the ROG is of particular importance for the utilization of offshore wind energy, as it offers the first opportunity to establish principles and goals of spatial planning in regard to the economic and scientific use, the guarantee of the security and the facility of maritime traffic as well as the protection of marine environments of the EEZ. In 2005, approx. one year after the expiration of the conversion deadline, the Bundestag passed the Act introducing a Strategic Environmental Assessment as an amendment to the law on EIA, (Publication of the amendment of EIA law UVPG v. 25. 6.2005, BGBl. I, 1757.) in which the fundamental rules for the execution of the SEA were defined.[4]

In all brevity the process of SEA can be outlined as follows (SCHOMERUS/BUSSE, NordÖR 2005, 45 ff.):

The so-called **Screening** stage serves to answer the question of whether or not a plan or program requires an SEA in the first place. Within the context of the restrictions of the United Nations Convention on the Law of the Sea (UNCLOS) in the EEZ, there are two possibilities of planning related area designations: firstly the spatial planning according to § 18 a ROG, and secondly a designation in especially suitable areas as described in § 3 a of the Marine Facilities Ordinance (SeeAnlV). According to No. 1.6. and 1.7. of Appendix 3 of the EIA law, a SEA is required in both cases. The strategy for wind power utilization at sea by the Federal Government in 2002 does not require a SEA to be carried out since no legal obligation exists for the production of this political programme (cf. Art. 2 a 2. of the SEA directive).

The so-called **Scoping** stage determines the investigative framework following the parameters of specialized legislation and in particular according to the material criteria as defined by § 3 of the Marine Facilities Ordinance (§ 3 SeeAnlV; on the endangerment of the marine

3 The final report on the project „Effects and Monitoring at the Regional Scale“ is in preparation and will be published in 2007 by Lexxion-Verlag, Berlin.

4 The name of the EIA law is no longer accurate. Since environmental assessment is a generic term for EIA and SEA, it should correctly be called law on environmental assessment.

environment and interference of maritime traffic). Beyond that, scoping has a participatory function. All public actors who are in any way environmentally affected including experts, non-governmental organisations etc if so required, are included. This serves to avoid superfluous assessments from the beginning. Different from the EIA, scoping in context of the SEA is an iterative, procedure-accompanying process. Investigation area, depth and scale must be adapted and changed if necessary due to realisations in the planning process.

The environmental report lies at the heart of the SEA. It is discussed in greater detail below. During the following public participation the so-called „affected public“ is to be included in the process, i.e. all persons inland or in neighbouring states whose interests are affected by the proposed plan or program. Necessarily included are organisations. Legal concernment is not required here. Also, a purely factual, „visual“ affectation leads to the authorisation of objection. The mere assertion of reasons of the common good is however not sufficient here. Appropriately, plans are to be laid out, not only in the Federal Maritime and Hydrographic Agency (BSH) but also in neighbouring coastal municipalities on the coast. According to regulations of the Environmental Information Act, a publication of plan documents is also to appear in the Internet.

The **compilation of the plan** presents an evaluation step in addition to the evaluation in the environmental report. The plan or programme and a summarising explanation regarding the inclusion of environmental considerations, as well as monitoring measures are subsequently to be disclosed. The way in which environmental considerations, statements and results of consultations have been included in the decision-making process are to be described. Furthermore a justification must be provided as to why the accepted version of the plan was preferred over alternative variations.

Monitoring is discussed in detail at the end.

3. The environmental report

The anticipated substantial impacts on the environment due to the execution of the plan or program shall be described and evaluated in the environmental report (SCHOMERUS / RUNGE / NEHLS et. al., 211 ff.). Therein not only the negative effects from an environmental perspective, but also the positive effects are to be included. Possible negative effects on certain species such as harbour porpoises or loons must be weighed in contrast to positive environmental effects such as the reduction of CO_2 emissions by the generation of clean, renewable energy. Special weight is to be put on the examination of reasonable alternatives. A difference is to be noted here in comparison to the Environmental Impact Assessment (EIA), in which only alternatives of the same type, such as route variations or dimensioning alternatives, are to be regularly examined. A wider spectrum shall be further considered to also include strategic alternatives. The „zero-variant“ is above all to be examined, i.e. the question of how environmental conditions would develop without wind- energy turbines.

3.1. Comparison of the environmental impact study of the EIA and the environmental report of the SEA

The environmental report of the SEA can be compared with the environmental impact study of the EIA - both are integrated into respective procedures in a similar way and both have an almost identical catalogue of natural assets. Nevertheless a series of differences exists, in which not only the chances but also the risks of the SEA may be pointed out in the management of planning conflicts. These differences may be substantiated in the following comparison between the environmental impact study in the framework of the EIA and the environmental report of the SEA.[5]

First of all, the major players are different. While the EIS is usually provided by private investors at their own expense, who according to the SeeAnlV must place a proposal for the authorization of wind farms, the public hand of the planning authority, in this case the Federal Maritime and Hydrographic Agency (BSH) is involved in the provision of the environmental report of the SEA. The constellation of interests is different: the investor naturally has a substantial financial interest in the implementation of the project and is ready to furnish payments in advance, while the authority responsible for the environmental report must account for the public welfare, despite clearly existing interests in the project. Their budget for ecological investigations is generally limited.

Furthermore the meaning of the aforementioned alternative assessment differs from the EIS to the environmental report. In the EIA, the alternative assessment is limited to linear purposes such as the construction of a certain wind farm. As far as a bound decision is concerned, as in the case of § 3 of the Marine Facilities Ordinance (SeeAnlV), there can be no tolerance in consideration wherein a reasonable alternative assessment would be possible (DAHLKE 2002, 472 ff). The purposes of the SEA, on the other hand, are more multidimensional, allowing for alternative assessment with a broad tolerance for consideration. This particularly applies to regional planning in the EEZ, whose purpose cannot solely be the expansion of offshore wind power, but rather one that encompasses a broad spectrum of topics and goals including commercial and non-commercial shipping, fishing, nature conservation, etc. Cumulative effects prove to be far more comprehensively assessed in the environmental report than in the EIS, especially in case of concretisation the plan or programme (BRANDT/RUNGE, 35 ff.; SCHOMERUS/RUNGE/NEHLS et. al., 211 ff.).

The greatest potential of the SEA shows itself in the comparison between the EIS and the environmental report with regard to **temporal dimensions**. The EIS is carried out directly before the planned project implementation in the context of the licensing procedure; it is carried out only once, and its time perspective is based on the expected life span of the facility. The temporal perspective of the environmental report is substantially larger in contrast. The environmental report is set in motion, notably before a possible project development begins and extends long after the expected life span of an individual facility. The completed assessment during the environmental report is furthermore repeated in the updating cycles of the plan or programme (i.e. when changes occur) as well as in parts of the subsequent monitoring. This far-reaching temporal dimension of the SEA strengthens the process character of the Strategic Environmental Assessment.

A comparison of the **spatial dimensions** is particularly decisive for the larger spectrum of the environmental report. The spatial coverage of the EIS is pinpointed and project-related, the area to be examined extends locally or at best regionally. The environmental report is different: it refers to wide reaching land uses, considering potentially effected areas on a regional or even global scale - keyword *climatic protection*. Such a broad spatial interpretation of the SEA requires an adjustment of scale by site survey and evaluation methods.

Pursuant to how they are categorized in § 2 par. 1 of the EIA law, the natural assets of the EIS are to be specified at a regional scale. In principle the same catalogue of assets applies for the environmental report of the SEA as those, which are defined by the EIA law. However, in the case of the SEA this catalogue is to be extended to the supra-regional scale,

[5] A specific study about the differences between SEA and EIA can be found in SHEATE/BYRON/DAGG/COOPER, Imperial College London Consultants, 2005.

whereby questions of biodiversity or climate are given new priority. Effects concerning migrating species, global climate changes, or questions of cross-regional pollutant transport may be secondary at the project level but receive greater precedence by the implementation of regional land-use plans or programmes.

Uncertainties and knowledge gaps must be taken into account in both the EIS and environmental report of the SEA (SCHOMERUS/RUNGE/NEHLS et. al., 230 ff). In the context of the EIS, it is to be noted that prior knowledge concerning environmental conditions in the EEZ is still incomplete – until now there has been relatively little experience with offshore wind technology. These uncertainties also play a role in the environmental report, but are again larger in scale. The diversity of effects is larger, the spatial spectrum broader and the prognosis periods are on a more long-term basis. The SEA must therefore be able to handle greater knowledge inconsistencies as compared to the EIA. This increased knowledge uncertainty in the SEA requires special control mechanisms. Appropriate instruments for this include among other things the de-stratification of the EIA (investigations are concretised at the project level), a carefully considered, problem-appropriate monitoring and a regular updating of planning, as well as the environmental report over long-term time intervals.

3.2. The issue of climate protection

The EIA law's catalogue of natural assets is comprehensive. The climate is expressly mentioned in § 2 par. 1 no. 2. While the micro and meso-climate stand in the foreground of the EIA at the project level, the macro-climate is of greater importance at the regional planning level of the Strategic Environmental Assessment. Climatic protection is no foreign concept to the SEA; this has already been recognized in the British handbook "Strategic Environmental Assessment and Climate Change: Guidance for Practitioners ". The British environmental agency has devoted an entire manual of guidelines solely to this topic (see http://www.environment-agency.gov.uk/commondata/105385/sea_climate_change_905671.pdf).

46% of harmful CO_2-emissions arise from the generation and transformation of energy production. This sector is thus a far cry from households, traffic, trade and industry. The contents of the SEA therefore include aspects of climate change and air pollution control by plans and programs for energy supply. Pursuant effects on natural assets are to be regarded as issues of great relevance in the environmental report. Despite the fact that the climatic and air pollution effects caused by offshore wind turbines are marginal, this topic is essential in the context of the zero-alternative assessment. With a pending SEA for the entire German EEZ, all German offshore wind energy must undergo assessment. The environmental effects are to be compared with conventional energy production facilities to the same extent of complexity. The reduction of climate and air pollution effects sways the balance heavily in favour of offshore wind energy utilization.

Good practice deems that the breadth of the environmental assessment is adapted to the expected environmental effects. Within the framework of the SEA for offshore wind energy utilization projects, under the criterion of spacious effects not only effects at sea, but also on land are of importance. Nevertheless a practical planning requirement also exists in order to optimally reduce the complexity and to place the effects to the planned area in the foreground of the environmental report. A clear gradation of more general synopses, special literature studies and site-related investigations is hereby advisable for the report. If at all possible, prognosis of effects should be taken down to marine level.

The ecological report contains new data, which, as was recently published in the world climatic report of the Intergovernmental Panel on Climate Change in 2007, is to be considered and updated when new knowledge comes into play (see http://www.ipcc.ch/). As is the case for the common abiotic natural assets, research concerning climatic effects is equally important for common biotic natural assets. Among other things, atmospheric warming can bring about a rise in total biomass. A rise in species numbers and individual numbers, as well as an increase in total biomass of floor-bed fauna is likewise probable for benthos. Species shifts among fish can also be a result, as well as the loss of habitats and a shortage of nourishment for avifauna. Altogether a rise in non-native invasive plant and animal species is to be expected with unforeseeable consequences for domestic ecological systems.

One of the questions dealt with in the research project is whether effect chains can be concluded regarding climatic changes and air pollutant effects, and whether this is relevant in the implementation of the SEA. In other words to what extent this can be represented quantitatively is asked; how much avoidance of damages is possible and whether this can be considered in the planning context by a weighing up of interests. The CO_2-reduction potential which will presumably be obtained by the intended development of offshore wind energy facilities, must first be determined. For example, the world-wide emission of climatically relevant gases was used as an initial basic measure. In the next step, the CO_2-emissions of energy production were determined globally and specifically for Germany. In a national context these figures were broken down into gross electricity production. Compared with the potential generation of electricity by offshore wind energy, a figure of 14% is arrived at. CO_2-output caused by gross power production in Germany is reduced by this figure.

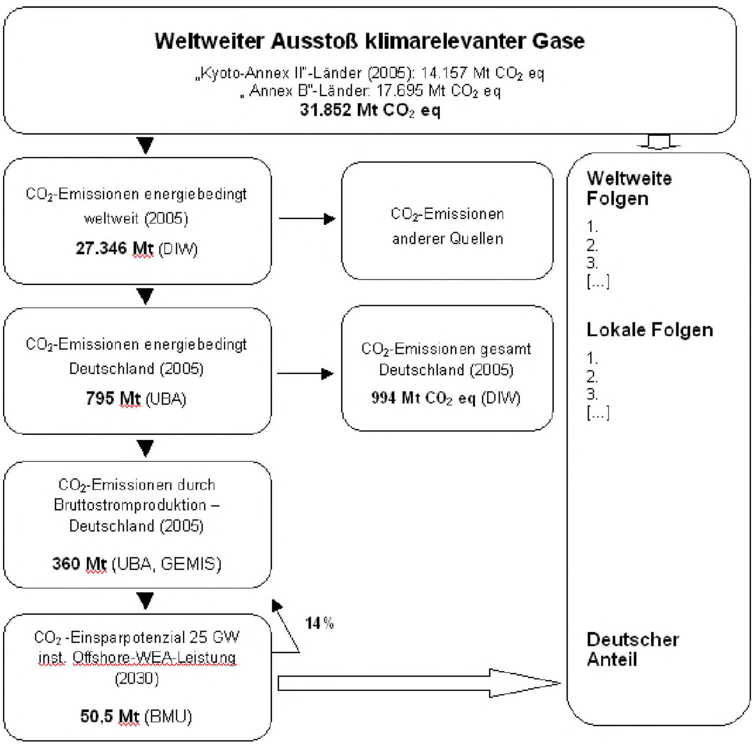

Figure: Greenhouse gas emissions, CO2 reduction potential by offshore wind power utilization and climatic sequences on the basis of the yearly 2005 (own illustration)

As a result of the compiled research, the following points are to be derived:

1. The expected effects of climate change and specifically energy related pollutants by large-scale emissions can be described and differentiated for a multiplicity of marine natural assets.

2. Cause and effect correlations are quantitatively difficult to determine, due to the greater regional scale and existing prognosis uncertainties. However, a qualitative description of the expected effects based on recent knowledge serves the overall consideration and the decision-making process.

3. The attainable CO_2- and other air pollutant reduction associated with offshore wind energy utilization can be comprehensibly determined and standardized. This data serves as evaluation criteria in the environmental report and where appropriate as a measure for comparing areas of differing CO_2- reduction potentials.

4. Monitoring

The new legal obligation for planning supervision according to German law has few binding regulations, allowing greater tolerance for authorities responsible for plans and programmes (BALLA 2005, 131 ff.; BRINK/RUNGE 2004, 273 ff.; BUNGE 2005, 124 ff..; RODER, in: HENDLER (Hrsg.), 225 ff.).

Monitoring must already be included in the environmental report. This serves above all to compare the plausibility of prognoses with the reality of the situation. It seeks out unexpected effects. It supervises the implementation of plans with regard to substantial environmental effects. It controls the execution and/or effectiveness of avoidance- and mitigation measures and draws conclusions for the total regional situation.

Monitoring is also vital in the matter of unforeseeable reciprocal effects in the EEZ. It can be understood as a quality control for the environmental report. The comprehensive monitoring at the plan and programme level is widely applied, yet exhibits few similarities with the surveillance of facilities, e.g. such as that according to the Federal Control of Pollution Act (BImSchG). In as far as possible, such existing surveillance mechanisms should be integrated into the monitoring to avoid doubled efforts.

Key points of the monitoring process should be clarified promptly and if necessary according to § 14m of the EIA law as specified with the acceptance of the plan or programme. These include:

<u>The establishment of goals and focal points</u>

The larger the uncertainties connected with the results of an SEA are, the more useful monitoring is, whether these reflect objective knowledge limitations or the restriction of data acquisition based on literary sources. Monitoring should therefore refer to particularly uncertain prognoses in addition to well-known or potentially substantial environmental effects.

<u>Financing</u>

Financial requirements stemming from investigation methodology and -frequency must be coverable. Otherwise a monitoring programme could be considered superfluous. Clarifying resource requirements and their necessary coverage requires early preparations (proposals, referenda), which lie to a large extent outside of the actual planning.

<u>Implementation authorities</u>

Implementation institutions must be clearly identified. Mere allocation is not enough. A formally declared agreement with the assigned institutions is necessary.

Controlling authorities

Although not a binding requirement, the involvement of multiple independent experts serves to gain acceptance of plans and programmes. Different stakeholders together with interested representatives of the public-sphere may merge to form advisory committees for the execution of monitoring measures.

Deadlines and durations of single controls and the filing of reports

In order to ensure the validity of the monitoring, timely deadlines and the duration of intended investigations should be specified.

Methodology

The methodology of the monitoring must correspond to the respective plan and thematic intentions.

Addressees of the monitoring report

Results of the SEA are to be handed over to several carriers of public interests. This is to say that such a group shall also be known as the „addressee circle“ of the monitoring report.

Consequences in the case of plan and/or program deviation

The results of the monitoring should allow consequences in the form of corrective measures during further implementation of the plan. Taking all possible results into consideration, it may be difficult to predict which conclusions should be drawn, in which cases. In individual cases however, certain consequences can be linked with certain effect thresholds.

An inclusion in the context of the gained information via monitoring is possible both on plan and project levels. At the plan level the adjustment of the plan is possible, either by changing problematic designations, or by designation of other possible compensation measures. An obligation for adjustment however, does not exist. An adjustment at project level is likewise possible. If in the context of the monitoring, negative effects on the marine environment appear as a result of realized projects, project permission can be subsequently adapted according to § 4 par. 3 SeeAnlV by additional arrangements.

5. Conclusion

Generally it can be said that the SEA does not present a universal remedy for all problems of spatial planning in the EEZ nor can it replace the EIA at project level. SEA and EIA should recognize and support each other mutually. Above all, a well thought-out stratification is necessary.

The Strategic Environmental Assessment serves as a suitable instrument for the planning of offshore wind-energy utilization, not only at the level of spatial planning in the EEZ, but also for the designation of suitable areas according to SeeAnlV which regulates spatial and lasting effects in the planning process. The SEA can only be efficient if it obtains binding legal status in relation to the subsequent project planning. For this purpose, the SeeAnlV must be amended by a regional planning clause (BÖNKER 2004, 537 ff.; MAIER 2004, 103 ff.; SCHOMERUS/RUNGE/NEHLS et. al 2006, 77 f.).

SEA in the planning of offshore wind power utilization clearly increases the importance of environmental and climate protection. The position of environmental aspects can thus been strengthened and can be better argued for. This includes the securing of participation rights of the public concerned.

Finally the implementation of the plans by the government is facilitated, according to strategic reports with necessary consideration of the positive aspects of offshore wind-energy utilization - in particular regarding climate protection. The SEA is therefore not an instrument for the prevention or hindrance of offshore wind-energy utilization, but rather serves a higher quality of its planning and implementation.

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Assessment of effects on the marine environment in the environmental impact assessment of offshore wind farms

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Abstract

The German ecological research on possible environmental impacts caused by offshore wind farms has produced many conclusions about the fauna of the North and Baltic Seas and about possible consequences of offshore wind farms on the marine environment. These results about potential impacts of offshore wind farms to the different organisms of the marine environment cannot directly be used for the drafting of the environmental impact study within the approval procedure of offshore wind farms. A "translation" based on a systematic analysis of the research results, to the legal requirements of the planning instruments is therefore needed.

Within the research project „Consideration of impacts to the marine environment during the approval of wind farms in the Economic Exclusive Zone (EEZ)" funded by the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety and the Projektträger Jülich, the natural scientific results have been analysed and processed for the development of practical advices that may give methodological requirements for the possibly decision-relevant impact relations.

Introduction

In order to avoid negative effects on the marine environment, environmental issues need to be carefully considered in the planning and decision making process with regard to the expansion of offshore wind energy use.

The approval procedure is in accordance with the Marine Facilities Ordinance (SeeAnlV). Under § 2a SeeAnlV, the applicant is obliged to carry out an environmental impact assessment. The approval is given within a „bound decision". That means that the approval can only be denied to the applicant if reasons for refusal under § 3 SeeAnlV are present. Accordingly, the approval i. a. must be refused „if the marine environment is endangered".

Direct scientific conclusions science about potential impacts of offshore wind farms to the marine organisms cannot be directly used for the drafting of the environmental impact study. Therefore a "translation", based on a systematic analysis of research results, to the legal requirements of the planning instruments is needed.

In the research project „Consideration of impacts to the marine environment during the approval of wind farms in the Economic Exclusive Zone (EEZ)" funded by the Federal Ministry for the Environment, scientific results have been analysed and processed for the development of practical advices that may give methodological requirements for the possibly decision-relevant impact relations. Based on the currently available experience in the approval procedure of offshore wind farms in the German EEZ, a case study analysis of environmental impact studies and approval notices has been made with focus on their relevance in the decision making and on the methods of assessment of the impacts. On the basis of a literature review and case study analysis, methodological advice for a decision-oriented assessment of impacts of offshore wind farms was developed. Further advice for the survey, assessment and consideration of cumulative impacts were developed in the research project (PETERS et al. in prep.).

Case study analysis of environmental impact assessments of planned offshore wind farms

The case study was specially focussed on the methodological process of the central procedural steps in the environmental impact assessment within the approval proceeding of offshore wind farms in the EEZ.

On the one hand the environmental impact studies, carried out from the assessors, were examined with a focus on the methods of survey and assessment. On the other hand approval notices and refusal notices by the authorising authority, the Federal Maritime and Hydrographic Agency (BSH), that were available until October 2005 have been analysed on the used methods of assessment of the endangerment of the marine environment by an offshore wind farm in terms of § 3 SeeAnlV. The methods were subsequently compared[6].

Inventory survey and assessment of the stock

The assessors make wide investigations on the stock inventory of existing natural assets. The results of the survey are introduced in the description of the stock inventory and in the assessment of every natural asset. Investigations about the stock also provide information for the impact prognosis and impact assessment.

The case study showed that the used methods of stock assessment in the studies differ from the approval notices. The stock assessment in the environmental impact studies aids in the identification of the significance of the natural asset's stock. The authorising authority uses the stock population assessment for resting birds, for example, for the identification of the necessity of consideration of a species in the next procedural steps- the impact prognosis and impact assessment. Some species may be determined in this process to have a special status of conservation and that are especially sensitive to offshore wind turbines.

Impact prognosis and impact assessment

During the impact prognosis differentiated between the natural assets the assessors note impact factors that are differentiated between project phases[7]. Furthermore they describe possible impacts oriented on the sensitivity of the particular natural assets.

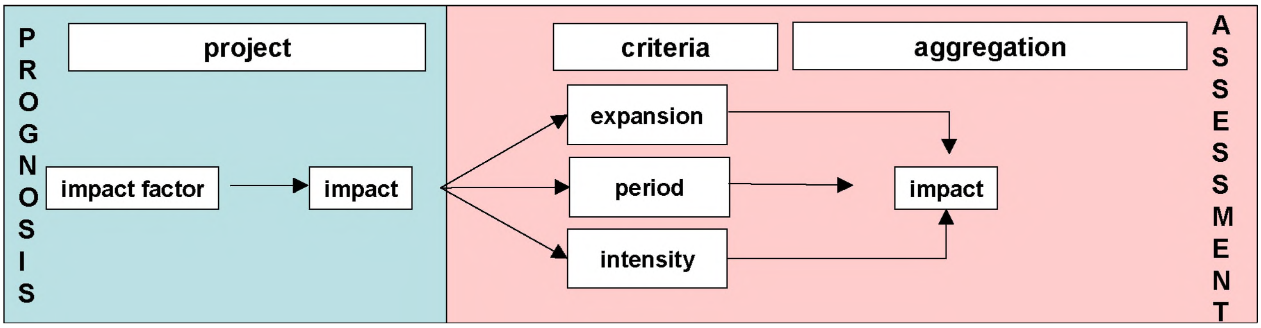
For the assessment of the widely described impacts, criteria such as „time period", „expansion„ and „intensity" are used. These are classified with ordinal scales and are attached to the particular impact (fig. 1). The assessments of the different impacts through the particular criteria are summarized in several steps of aggregation. Then a conclusion

[6] The case study analysis has been made within a diploma thesis (MORKEL 2005). It is discussed more detailed in an article in UVP-Report (MORKEL 2006).
[7] Construction phase, installation, operation phase.

about all of the impacts by the offshore wind farm to the natural asset can be made (high, medium, low). This occurs with a rating matrix.

The significance of the natural asset's stock and the whole impact of the project are blended with each other. If the stock population of resting birds in the project area was assessed with a medium significance and all the impacts of the wind farms were classified as medium, then in the environmental impact studies it is unlikely that the natural asset could be endangered.

Environmental Impact Studies



Federal Maritime and Hydrographic Agency

number of affected individuals	83 individuals (project) 557 individuals (including cumulative offshore wind farms)
1% of the biogeographic population (divers)	1.100 individuals
no endangerment	83 individuals < 1.100 individuals 557 individuals < 1.100 individuals

Figure 1: Comparison of the methods of impact assessment on the example of the natural asset of sea and resting birds

However, the authorising authority makes quantitative evaluations in the example of disturbance of sea and resting birds caused by offshore wind farms. The table above in fig. 1 shows the method for the assessment of the intensity of the impact on the example of divers in the area of offshore wind farm Amrumbank West, which is used by the authority. The number of possibly disturbed divers there is compared to a population-biological threshold. This threshold is oriented on the criteria of 1 % according to the Ramsar Convention. If the number of affected individuals exceeds 1 % of the biogeographic population of the species, another assessment of the impact correlation on the basis of a matrix will be made. The input parameters of this matrix are, different from the use of the matrix in the case studies, concretely defined. On the one hand they are oriented on the intensity of the impact (% of loss of population / habitat) and on the other hand on the ecological significance of the habitat (e.g. NATURA 2000).

Conclusions of the case study analysis

The case study analysis shows that the methods used in all of the environmental impact studies differ from the one used by the authorising authority. They have only little influence on the assessment and decision of the authority. This is caused by the different assessment procedures of the assessors and the authority.

It is necessary to focus the procedure in the environmental impact studies on the leagally-standardised decision of the approval. Therefore the environmental impact studies should give exactly this information that prepares and supports the decision made by the authority and the assessment of impacts to be made in this context. The definition of the necessary information should already be made in the earlier process of scoping (KÖPPEL et al. 2004, 204f). Only then can the environmental impact study set up a decision in the process of a „bound decision" of offshore wind farms. This improves the possibility for the authorising authority to use information from the environmental impact studies or to be geared to the advice of the assessment.

Development of models for the assessment of impacts caused by offshore wind farms

To be able to more efficiently include environmental issues into the decision-making process, some assessment models have been developed within the research project. With these models the impact correlations and the impacts can be assessed. On the basis of the investigated intensities of impacts, the authority can assess whether the possible impacts caused by offshore wind farms may be significant, with regard to the legitimacy of the project.

As a basis of the impact analysis, it is first necessary to analyse the correlations between the project and the different natural assets and factors of the marine environment (KÖPPEL et al. 2004, 224). A basic model for the analysis of this impact correlation provides a cause and effect chain. With this model the different impact correlations can be pointed out. The developed prognoses for the assessment are based on the model of cause and effect chain.

Because of the differences of impact correlations between the natural assets and offshore wind farms assessment, models have been developed for several impact correlations, which have been identified as especially significant for the decision making process. These impact correlations concern, for example, natural populations of harbour porpoises, migratory birds and sea and resting birds:

- Hearing impairment to harbour porpoises caused by the construction,
- Displacement of sea and resting birds caused by disturbance,
- Collision (strike risk) of migrating birds,
- Barrier effect for bird migration.

Impact assessment model on the example of the displacement of sea and resting birds

According to the results of natural scientific research, e. g. the impact correlation of displacement of sea and resting birds has been identified as relevant to the decision-making process. The impact assessment model developed by the Berlin University of Technology will be introduced by this impact correlation.

The dimension of the impact of displacement of sea and resting birds caused by offshore wind farms can be assessed through impact factors like basic structural characteristics of the planned offshore wind farm (size, illumination, height and number and arrangement of turbines) and on the other hand the sensitivity of the species against the impact factors of offshore wind farms and furthermore of other cumulative offshore projects. How the factors influence the assessment of the impact intensity can be shown in the presented “when-if correlations” (tab. 1). So it is assumed, for example, that the bigger the wind farm is, the stronger the displacement will be and then the loss of habitat for sea and resting birds.

Table 1: Sea and resting birds: impact correlations of habitat loss caused by displacement

Impact factors	Type of impact	Acquisition or measurement parameters
Size of wind the farm		
Extent of the wind farm	The larger the wind farm area, the stronger the effect of displacement and habitat loss.	km²
Number of turbines	The more turbines, the stronger the effect of displacement and habitat loss.	Number of turbines
Effect intensity		
Arrangement of the turbines	The smaller the distance between the turbines, the stronger the effect of displacement and the less is the suitability of the area as a habitat (species specific).	Number of turbines / km²
Height of the turbines	The higher the turbines, the stronger the effect of displacement and habitat loss (species specific).	Height of the turbines in m
Effect intensity of cumulative wind farms		
Cumulative wind farms	The more and the nearer other wind farms, the stronger the disturbance.	Number and distance of other wind farms
Local occurrence of the species		
Combination of species	--	species
Number / density of seabirds	The higher the density of individuals, the more individuals will be effected by habitat loss.	Number of seabirds / km²
Species sensitivity		
Sensitivity to construction and operation of wind turbines	The more sensitive the species, the stronger the effect of displacement.	Seabird-Sensitivity-Index Behaviour pattern of the species Number of displaced individuals
Avoidance capacity		
Accessibility of avoidance habitats	The worse the alternative, the stronger the effect of displacement and habitat loss.	Number of seabirds, which do not reach an alternative habitat. In extreme cases the number of displaced animals has to be completely included as loss of individuals.
Habitat associations	The stronger the binding to special habitats, the stronger the effect of habitat loss.	
Other turbines in the surroundings	The more and the nearer other projects are located in the surrounding, the less the avoidance capacity.	Distance to cumulative projects (km).
Ornithological significance of the species		
Task of this source for the overall population	The more important the displaced source, the stronger the disturbance.	Type of consequence for the overall population in case of loss of the subpopulation
Legal significance of the species		
Conservation status of the species (FFH, Bird-Directive, Red Lists)	The higher the conservation status, the greater the endangerment of the marine environment is concerned.	Conservation status of the species
Mitigation and avoidance		
Compliance of minimum distances between the turbines that can preserve the functions of habitat for several species (depending on species specific avoidance distance).		

The central criterion for the relevance of the impact caused by displacement is the number of displaced individuals and the impact on the whole population.

Through the concurrence of different impact factors in regard to the loss of individuals a calculation for the number of displaced individuals was developed (tab. 2).

The main parameters for the calculation of the number of displaced individuals are the size of impact area of the wind farm (on the side of the project) and the density of individuals in the area of the wind farm (on the side of the marine environment). To begin taking the size of the wind farm into account, in order to calculate the potential habitat loss of sea and resting birds, a distance disturbance is to be included, in which some species are recognized to stay towards the outer turbines of the wind farm (step A). For instance, divers keep a distance of 2000 m from the outer turbines. The density of the occurrence of a species is also considered in the calculation model. The occurrence of a species in an area varies so that several investigations have to be done (depending on weather, season, etc.). Minimum and maximum values of the density of a species in the investigation area can be determined and can be integrated into the calculation model (B).

The multiplication of the density of a considered species with the size of the wind farm, including the disturbance distance, can determine the number of potentially displaced individuals (C).

Structural characteristics of the wind farm like, for example the illumination, the intensity of service or others, may have an influence on the intensity of the disturbance caused by the wind farm. The impact intensity of the wind farm can be included into the calculation of the habitat loss through a factor of impact intensity (D). Likewise, the displacement sensitivity of a particular species can be integrated through a factor of displacement sensitivity (E). The number of potentially displaced individuals can be multiplied by these factors. The result is then the number of displaced individuals (F).

The importance of habitat loss for the population can be evaluated by analysing which significance the lost habitat has for the species and whether there are alternative avoidance habitats. If there are no avoidance habitats available, a total loss of individuals will be possible. The backup capacity is included into the calculation model with a avoidance capacity factor (G) that is multiplied with the number of displaced individuals of a species to be able to assess the reduction of the population size.

Table 2: Impact Assessment Model of habitat loss of seabirds caused by the displacement effect of offshore wind farms

Main Parameters	Maximum	Minimum	Notes and possibilities for further differentiation
(A) Size of the effective area of the wind farm	Area of the wind farms plus avoidance distance. This means for rectangular areas: (side length A of the wind farm + 2 x species specific avoidance distance (km)) x side length B of the wind farm + 2 x species specific avoidance distance (km)) *e.g. (9 km +2x2 km) x (6 km + 2x2 km) = 130 km²*		
(B) Density of individuals in the intended wind farm area	Largest determined individual density in the wind farm area (individuals/km²) *e.g. 1.5 individuals / km² (incl. Correction factor)*	Smallest determined individual density in the wind farm area (individuals / km²) *e.g. 0.6 individuals / km² (incl. Correction factor)*	Differentiation of seasons because of different functions of the areas for the population and avoidance capacities.

(C) Number of potentially displaced individuals	A x B Wind farm effective area (km²) x individual density in the intended wind farm area (individuals / km²)		
	Max. 130 km² x 1.5 individuals / km² = 195 effected individuals	*Min. 130 km² x 0.6 individuals / km² = 78 effected individuals*	
(D) Displacement intensity of the wind farm (Displacement factor)[8]	The wind farm effects above average. • High service intensity • Special illumination • High noise during development *=> Displacement factor 1,3*	The wind farm effects below average. • High distances between turbines • Low service intensity • Special illumination • Low noise development *=> Displacement factor 0,7*	
	Supposition: Displacement factor 1		
(E) Displacement sensitivity of the species (sensitivity factor)[9]	The species is very sensitive. All individuals in the effected area will be disturbed *=> Sensitivity factor 1*	The species is non-sensitive. No individuals in the effected area will be disturbed *=> Sensitivity factor 0*	
	Loon: Sensitivity factor 1		
(F) Number of displaced individuals of a species	C x D x E Number of effected individuals x displacement factor x sensitivity factor		
	Max. 195 effected individuals x 1 x 1 = 195 displaced individuals	*Min. 78 effected individuals x 1 x 1 = 78 displaced individuals*	
(G) Importance of this habitat for the species / Backup capacity	The displaced individuals cannot relocate to other areas so that the population will be reduced through the number of displaced individuals. Avoidance capacity 0% *=> Avoidance capacity factor 1*	The individuals can reach other areas so that the population will not be reduced through the habitat loss. Avoidance capacity 100% *=> Avoidance capacity factor 0*	
	Loons in the area: Avoidance capacity factor 1 (no backup capacity)		
(H) Reduction of population size	F x G Number of displaced individuals x avoidance capacity factor		
	Max. 195 displaced individuals x 1 = Population size reduction of 195 individuals	*Min. 78 displaced individuals x 1 = Population size reduction of 78 individuals*	

Which differences of the development of the population can finally be tolerated and which are to be assessed as relevant, so that a planned project has to be refused, is dependent on the social evaluation of the effected species or population. In the simplest case it could be determined that every negative development of a population that is caused by a project represents an endangerment of the marine environment and could lead to a refusal of the approval of a project.

Whether negative effects on a population could also represent an endangerment of the marine environment, even if causes of negative developments cannot be verified, is dependent on the significance of the occurrence (state of conservation, merit of preservation). The higher the merit of preservation of a population is appraised, the smaller the tolerable negative changes. This is finally a political decision and not the task of scientists.

[8] If the species-specific sensitivity factor is 1 and from an average impact intensity of a wind farm all individuals of a species are displaced, the displacement factor > 1 will not have any influence on the result of the calculation. No more individuals can be displaced than are present in the area.

[9] The sensitivity factor has to be defined for each species, e.g. on the basis of SSI (GARTHE & HÜPPOP 2004).

Conclusions and perspectives

The case study analysis of the environmental impact studies shows that the procedure used by the assessors differs from the used procedure in the appraisal notices. It is therefore needed to directly link the environmental impact studies to the legally standardised decision making process. Then the environmental impact study can more effectively support the decision.

The impact assessment model developed in the research project is concentrated on impact correlations that have actually been identified to be able to be assessed as an endangerment of the environment. This would imply a significant relief of contents of the environmental impact studies. If in the future e.g. other impact correlations should be assessed as relevant through further experience (e.g. for the natural assets fish and benthos), more assessment models can be developed.

Different impact correlations and their intensities can be assessed with the impact assessment model. It provides information about the dimension of the impact caused by the project on a semi-quantitative level. To be able to find a concluding evaluation, the predicted amount of affected or killed individuals has to be compared to the whole stock inventory of a population. This is the main cause for the lack of thresholds in many cases that can give information as to whether a predicted reduction of the population may involve an endangerment of the marine environment or whether it may be tolerable.

If it is possible to agree on adequate thresholds in the near future, this semi-quantitative model provides a clear and comprehensive decision-making basis for the approval of offshore wind farms. As long as there is a lack of thresholds, this model helps to structure the surveys and the assessment. On the one hand it supports the practitioners with the drafting of environmental impact assessments and on the other hand it supports sciences and administrations in further methodological development.

If this impact assessment model was used for all planned offshore wind farms, it could bring advantages in the comparability of the impact potential of different offshore wind farms through the quantitative assessment of the impacts. This possibility is especially interesting with regard to the assessment of cumulative impacts. Cumulative impacts are only secondarily handled and have no essential influence on the decision making process.

Furthermore, the question about the assessment of impacts in the decision-making process has to be answered. After the potential dimension of the impact is known it must be assessed by the authorizing authority to determine whether an endangerment of the marine environment according to § 3 SeeAnlV is to be expected by the potential dimension of the impact. Therefore thresholds can be used that need to be defined in a convention building process.

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Avian avoidance behaviour and collision risk: Results from post construction monitoring of the Danish offshore wind farms at Horns Rev and Nysted

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Abstract

The hazards presented to large, long-lived water birds by the Horns Rev and Nysted offshore wind farms in Denmark were investigated during 6 years of pre- and post-construction studies. Aerial surveys, radar, infra-red video monitoring and visual observations confirmed that most of the more numerous species showed avoidance responses to both wind farms. Behavioural avoidance responses caused effective habitat loss (measured as reduced bird densities between turbines post construction by aerial surveys) of divers at Horns Rev and long-tailed ducks at Nysted, despite their habitat remaining largely unaffected. Other species occurred in too few numbers to assess or did not show clear displacement effects. These effects were highly species specific, the extent of habitat loss was small and involved relatively small proportions of the populations concerned, and were therefore likely of little biological significance. Flying birds showed avoidance responses to both wind farms, although responses were species specific and differed by day and night. Overall, c.75% of all birds heading for both wind farms at 1.5-2 km distance avoided entering between the turbines. Those flying within the wind farm showed avoidance behaviours, such as altitude reduction, which further minimised collision risk. Of the 235,000 Common Eiders passing Nysted each autumn, a specifically designed stochastic model predicted collision rates to be 0.02% (45 birds per migration season); this low rate was confirmed by the fact that no collisions were observed by infra-red monitoring of one turbine. Whilst these two projects are unlikely to have had any major effects on the avian populations involved, assessing the cumulative effects of these and other human developments remains a future challenge. We would be cautious in applying the results of these studies directly to other offshore wind farms, other species and other areas.

Introduction

Denmark was the first country to construct two full production scale wind farms for electricity generation in the marine environment, following the erection of turbines in the North Sea at Horns Rev and in the south of the country off Nysted in 2002-2003 (ANONYMOUS 2006). Both projects were designed as demonstration projects, the result of a government decision to investigate the economic costs, engineering challenges and environmental effects of these offshore developments. As a result, full environmental assessments of the impacts on the environment from these two major projects were undertaken in advance of construction, with post construction monitoring to determine the actual effects. Migratory and marine birds figured prominently in these assessments and six years of investigations (both pre- and post-construction) have now been completed and recently published in a single report covering both sites (PETERSEN et al. 2006). As well as providing valuable insights into the challenges posed to birds at these two geographical localities, the experiences gained from these two major projects are important for guiding the identification of potential locations for future offshore wind farms based on ornithological considerations and for supporting the development of more effective environmental impact assessment and post-construction monitoring at other sites. For this reason, we here present a very brief overview of the results and conclusions from these studies.

Although there are many ways in which offshore constructions may affect birds, the major hazards presented to birds in the marine environment can be summarised under three major categories, two are the result of behavioural responses which cause avoidance, which may either cause (i) displacement of birds from their optimal feeding distribution and/or (ii) from preferred routes of movement. The third (iii) is physical collision with the turbine superstructures causing injury or death (but see FOX et al. 2006 for a fuller discussion of the issues).

Methods

Selection of critical species for investigation

It is simply not feasible or practical to make an assessment of the effects of the construction of offshore wind farms on all the different bird species that may potentially occur in a given area. For this reason, in considering the two projects, we were constrained to select key species using a series of well defined criteria. These included species:

- which enjoy special protection measures (e.g. under national or international legislation)
- for which the area is important at some stage in the life cycle (either numerically or nutritionally)
- that are vulnerable to wind farms (e.g. persistently fly at rotor height)
- that exhibit demographic sensitivity to additional mortality (typically species with high annual adult survival and low reproductive output, see DESHOLM 2006)

Displacement of feeding and resting birds

Birds may respond by physically avoiding the vicinity of turbines after their erection. Although the habitat and food availability may remain unchanged post construction, if the birds are reticent to approach to turbines within half the distance between them, the whole area of a wind farm will be lost as a potential feeding area ("effective habitat loss"). It was therefore necessary to describe the distribution of resting and feeding birds using the marine environment prior to and following the construction of the two Danish offshore wind farms. To do this, we developed methods of aerial survey from aircraft to construct bird density surfaces over extensive tracts of the offshore areas that would enable pre- and post-construction comparisons. This was undertaken to gather a "before" and "after" overview, based on geographically explicit data on the distribution and abundance of all avian species over as short a time frame as possible using a surveillance platform that caused the least disruption to the natural distribution patterns of the birds involved. Full details of the techniques used can be found in PETERSEN et al. (2006) and references therein.

Displacement of preferred flight routes

Birds may also choose to avoid flying near the turbines, which cause a modification to flight routes (e.g. daily routes between night time roosting areas and daytime feeding areas, or between feeding areas and terrestrial breeding colonies) or to long distance migratory corridors. For the former, the increased energetic demands may be very significant when adding substantial flight distances to daily commuting patterns; for long distant migrants, the effects may not be so marked depending on the length of an entire migration corridor. Both types of displacement require some assessment of the changes in direction, height and speed of flying birds to assess how the different species modify their behaviour in the face of the creation of an offshore wind farm. This needs techniques, which can define the movements of individual birds or flocks of birds in three-dimensional space in such a way that it is possible to make comparisons between the pre-construction and post-construction trajectories flown by birds to describe their avoidance patterns. This has required the development of new remote sensing techniques, including marine navigation radar and infra-red video imagery techniques (or Thermal Animal Detection System, TADS see DESHOLM 2003, DESHOLM et al. 2006).

Collision rates

Birds may also show no avoidance of large offshore constructions with the result that those flying near the turbines collide with them, causing death or mortal injury. Unlike on land, there are great difficulties associated with recovering corpses from under turbines at sea, so again, innovative approaches have been adopted to predict and calculate actual collision rates (again using remote sensing techniques, see DESHOLM et al. 2006, PETERSEN et al. 2006) and in particular to model collision risk rates based on observed intensities of flight passages which can be verified by infra-red video imagery monitoring post construction (CHAMBERLAIN et al. 2006, DESHOLM et al. 2006, DESHOLM & KAHLERT 2006). Because the entire Baltic population of the Common Eider *Somateria mollissima* migrates in and out to their winter quarters in eastern Denmark, Wadden Sea and southern North Sea, special attention was given to modelling collision risk and measuring actual collision rates in this species at Nysted, as the species is also a long-lived and large-bodied water bird with relatively low annual reproductive success.

Results

Selection of critical species for investigation

Using the criteria established above, our studies at both sites concentrated most upon long-lived large bodied seabirds (such as divers, sea ducks, gulls and auks), which were not only abundant, but were also those most demographically susceptible to even slight increases in annual survival rate. This was not to imply that the other species were not important, but the study of many of the less numerous species was also beyond the logistic possibilities at the two study sites and of lesser relevance in terms of population impacts.

Displacement of feeding and resting birds

Aerial surveys throughout the annual cycle at both sites showed that most avian species were not sufficiently numerous or showed too great a variance between surveys to statistically detect any clear displacement effects by comparing pre- and post-construction distributional data. Displacement from the area of the wind farm post construction was statistically significant amongst divers (*Gavia* spp., but most commonly *Gavia stellata* at Horns Rev where they showed almost complete avoidance post construction) and long-tailed duck (*Clangula hyamelis* which showed significantly reduced densities at Nysted post construction). Common Scoter *Melanitta nigra* showed extreme reticence to fly or forage between the turbines in the first three years of the post construction study, but have recently shown an increasing propensity to do so (unpublished data).

Despite the attraction of loafing gulls *Larus* spp. and Cormorants *Phalacrocorax carbo,* which use the turbine foundations for resting, no bird species showed enhanced densities post construction.

Displacement of preferred flight routes

Radar studies showed that birds generally avoided both Danish offshore wind farms post construction but that responses were highly species specific (PETERSEN et al. 2006). Some species showed gradual avoidance at long distance, potentially from the very first point of visual encounter with the turbines. Others made more dramatic changes in flight deflection close to (i.e. generally within less than 1 km) the outer turbines (DESHOLM & KAHLERT 2005, PETERSEN et al. 2006). Around 75% of bird radar tracks heading towards both wind farms at 1.5 to 2 km distance avoided going through the wind farm between the turbine rows and there was a similar reduction in the absolute number of tracks entering the Nysted wind farm post construction compared to pre-construction (PETERSEN et al. 2006).

Collision rates

Although the avoidance responses of feeding, resting and flying birds mean that turbines erected at sea do affect the local distribution, abundance and flight patterns of birds in the immediate vicinity, the corollary is that fewer birds come within the risk zone of the rotor blade sweep area, reducing the overall collision probability. Radar studies also confirmed that many Common Eiders entering the Nysted wind farm (i) re-orientated themselves to fly down between the turbine rows, frequently equidistant between the turbines, (ii) flew at lower levels (more frequently below the turbine sweep area than outside the park), (iii) take the shortest route out of the wind park once within the turbine cluster and (iv) flew above rotor height in darkness at night in contrast to daylight conditions. All four reactions (in addition to the majority avoiding to fly in the wind farm at all) further minimise the collision probability.

A stochastic predictive collision risk model was constructed to estimate the collision probability for Common Eiders passing the Nysted wind farm each autumn (DESHOLM & KAHLERT 2006). Using many measured parameters derived from the radar and TADS studies at Nysted, one thousand iterations of the model generated a prediction with 95% certainty that out of 235,000 Eiders passing the wind farm each autumn, 0.018-0.020% would collide with the turbines in a single autumn (equating to 41-48 individuals per autumn, DESHOLM & KAHLERT 2006, PETERSEN et al. 2006). It was predicted that such a low level of collision probability at the wind farm level would mean an extremely low frequency of collision at any one turbine and that TADS would fail to detect a single collision in the course of 2,400 hours of monitoring during the periods of most intense passage and this proved to be the case (DESHOLM & KAHLERT 2006, PETERSEN et al. 2006).

Conclusions

Displacement of feeding and resting birds

The relative loss of habitat to species such as divers, scoters and long-tailed ducks through effective habitat loss associated with turbine construction needs to be assessed in the context of the total feeding habitat available and the size of the overall populations involved. However, for these two development projects, the effect was highly species specific and the proportion of effective habitat loss was very small and therefore likely of no biological significance at either site. However, we should be cautious about the additive effects of many more such wind farms constructed along the migratory flyway corridors of these organisms, which may constitute a more significant cumulative effect in the future. Measurement and assessment of such cumulative effects remains a high priority when assessing individual project proposals along avian population migratory routes in the future.

Displacement of preferred flight routes and collision risk

Flying birds did show avoidance of both wind farms, although for logistic reasons it was not possible to gather data on flight trajectories at Horns Rev prior to construction. Such avoidance was highly species specific and differed by day and by night. Amongst those entering the wind farm area between the turbines, birds showed changes in behaviour that minimised collision risk. The collision risk model suggested very low levels of collision risk probabilities amongst the very dramatic migration of Common Eiders that pass through the vicinity of Nysted each autumn and spring and this was born out by the results of TADS infra-red video monitoring. The estimated c. 80-90 birds potentially killed annually compares with 70,000 shot each season in Denmark where the species is legal hunting quarry.

General conclusions

Whilst we are confident of the validity of our results from these detailed observations of two new offshore wind farms, based on comparisons of data collection before and after construction, we would be extremely cautious about extending these findings from just two (very different) sites in Denmark to other offshore wind farms, other species and other areas. We wish to stress that although the effects on birds from these two wind farms are considered to be minimal and are very unlikely to have major effects on any populations of birds occurring in the vicinity, they may have effects when taken together with other multiple human impacts which are current having effects on these populations. The prospect of the construction of many more such offshore wind farms being constructed in the immediate future along the common flyway corridors of species discussed here gives particular cause for concern, given that they will be constructed in generally similar habitats. We therefore urge that future projects undertake similar pre and post construction monitoring to those presented here to add to out knowledge of different areas, species and effects, and especially that the cumulative effects of all human development pressures on offshore species be undertaken as a matter of urgency.

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Collision risks at sea: Species composition and altitude distributions of birds in Danish offshore wind farms

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Abstract

This study investigates the collision risks of birds in operating offshore wind farms, focussing on all bird species present in the direct vicinity of the wind farms, their altitude distribution and reactions. The project was conducted jointly by BioConsult SH and the University of Hamburg in the two Danish offshore wind farms Horns Rev (North Sea) and Nysted (Baltic Sea) in the framework of a Danish-German cooperation and financed by the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU). Data were collected between March 2005 and November 2006, using a ship anchored at the edge of the offshore wind farms. In this way, bird species of all sizes could be considered. Daytime observations yielded data on species composition, flight routes and potential reactions of the birds. Radar observations provided altitude distributions inside and outside the wind farm area and also reactions. The results shall help to further describe and assess the collision risk of different species groups. Since data analysis is still running, exemplary results will be presented here.

114 species have been recorded in Nysted and 99 in Horns Rev, approximately 65% of which have been observed inside the wind farm areas. Migrating birds seem to avoid flying into the wind farms, whereas individuals present in the areas for extended time periods utilize areas within the wind farms. While a barrier effect exists for species on migration, resident species probably have a higher collision risk. Raptors migrating during daylight frequently enter the wind farm area on their flight routes, correcting their flight paths in order to avoid collisions. Radar results show that during times of intensive migration, the proportion of birds flying at high altitudes and thus above windmill height is higher than in times of low migration intensity. Consequently, there is a lower proportion of migrating birds flying within the risk area.

Data will be further analysed to describe altitude changes of birds approaching the wind farm.

Introduction

Germany intends to substantially lower its CO_2-emissions. One way to achieve this goal is to intensify the construction of offshore wind farms in the German waters. Consequently, plans and permissions exist for installing some 5 Gigawatt offshore, that is 15 offshore wind farms in the North Sea and three in the Baltic Sea (BSH 2007). These plans raise some worries, that above all migrating birds will be affected by these wind farms. Potential effects fall under three categories: 1) barrier effect – birds will avoid the wind farm areas and potentially avoid zones around these; 2) direct habitat loss caused by the wind mill structures; 3) collisions – additive mortality caused by collisions of birds with the wind mills. The Danish offshore wind farms Horns Rev, North Sea, and Nysted, Baltic Sea, have been in operation since 2002 and 2003, respectively (fig. 1).

Finding suitable locations for the construction and operation of the wind farms has been accompanied by Danish studies following the BACI design (before-after-control-impact). With regard to bird investigations concentrated on barrier effects and habitat loss (e.g. CHRISTENSEN et al. 2004, 2005) as well as on collisions risks (KAHLERT et al. 2005, DESHOLM 2005, 2006, DONG et al. 2006), the focus was on seabirds, diving ducks and species groups which migrate and / or stage and feed at both locations in considerable numbers.

To calculate collision risks, several parameters need to be considered. Technical parameters are: height of wind mill including the rotor blades, max. chord, pitch angle, rotor diameter, rotation speed and others. Biological data include: bird length, wing span, bird speed, “flapping or gliding” and others. Given these, additional biological data are needed:

- how many birds use the considered area (wind farm and surroundings)?
- how many birds use the area impacted by the wind mills?
- how many birds fly within the collision risk area, that is:
    - within the relevant altitude class
    - within the area swept by the rotor blades?

Once these data exist, a theoretical collision risk can be calculated (BAND et al. 2007, DESHOLM 2006); that is the probability with which a bird would collide with a wind mill if it does not take any avoidance action. It is known, however, that birds do recognize wind mills and react at large and small distances to avoid collision with the superstructures. Since exact data on these avoidance actions are unknown, except for some case studies, a 95% avoidance rate is assumed (BAND et al. 2007, ERICKSON et al. 2001). It has been shown for Danish offshore wind farms that by good visibility during the daytime e.g. Eiders correct their flight paths at about 3-4 km distance from the wind farms and this way take a minor detour to fly around the areas (KAHLERT et al. 2005). In bad visibility situations or at night-time, these avoidance actions take place at shorter distances. In cases where individual Eiders fly through the wind farm, they apparently chose a flight route between the wind mills keeping a maximum possible distance from them (DESHOLM & KAHLERT 2005). One must assume, that these behaviour patterns apply for most species, however, to varying degrees.

The actual collision rate depends largely on the avoidance rates. It has been shown, that a 10% variation of the technical or biometrical parameters changes the calculated collision risk by 5-10%. However, a 10% change – in this case lowering - in avoidance rate changes raises the collision risk 20fold (CHAMBERLAIN et al. 2006). Collisions increase the mortality of a population, depending on the population ecology of each species (life span, reproductivity, fecundity and age of first reproduction etc.). This effects the population development. Population models incorporate these data and can calculate the species-specific effects of this added mortality (e. g. REBKE 2005). Finally, the results of such model calculations must be tested in real-time situations. This means, predicted collision rates should be verified by effect-monitoring. Some exemplary collision studies have already been conducted for onshore installations (e.g. GRÜNKORN et al. 2005). However, to date, almost all attempts to quantify collision rates at offshore installations have failed to do so (see DESHOLM 2005, WIGGELINKHUIZEN et al. 2006).

In the framework of a Danish-German cooperation, the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) has initiated and financed a study to collect and analyze data and assess the collision risk in operating offshore wind farms.

Sites and methods

Sites

The investigations have been conducted at the two Danish offshore wind farms Horns Rev (North Sea) and Nysted (Baltic Sea) (fig. 1), in operation since 2002 and 2003, respectively.

Figure 1: The Danish-German North Sea and Baltic Sea and the position of the two wind farms Horns Rev and Nysted.

The ship was always positioned at some 100-200 m distance from the border of the offshore wind farms, from which it was expected that the seasonally specific bird migration would come from. In this way, birds flying towards the wind farm could be observed (fig. 2).

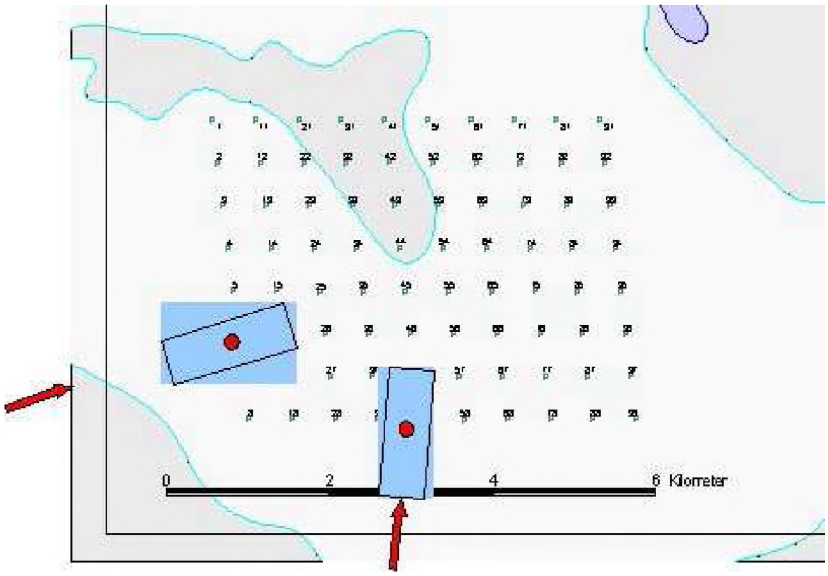

Figure 2: Two exemplary ship positions, also showing the observation range, here at Horns Rev during spring; migrating birds were expected to arrive from southerly or south-westerly directions. Red dots = ships; red arrows = expected migration directions; grey rectangles = observation range for visual observations and radar observations with the radar rotating vertically.

Radar observations

Two radars were used on each ship. A Decca BridgeMaster E was turned into a vertical direction (vertical radar), to measure numbers and altitudes of birds inside and outside the wind farms. A Raytheon Pathfinder was used in its normal horizontal position (horizontal radar), to register flight paths and potential bird reactions. Technical specifications can be found in tab. 1.

Table 1: Technical specifications of the radars used

	Decca BridgeMaster E	Raytheon Pathfinder
power output [kW]	25	10
frequency [MHz]/ wavelength [mm]	9,410±30 / ~31.86	9,410±30 / ~31.86
horizontal angle of radar beam [°]	1	1.15
vertical angle of radar beam [°]	24	~25
rotational speed [min $^{-1}$]	28	24
antenna length [mm]	2,440	1,830

The horizontal radar was used in a range of 2,780 m (1.5 nautical miles). The vertical radar was switched every 30 minutes between the ranges of 500 m and 1,500 m. Both radars ran continuously during the observation periods. We adjusted the vertical radar in such a way that it turned more or less parallel to the expected migration direction of the birds. At the same time, the radar had to be adjusted to turn more or less perpendicular to the wind farms side in order to be able to separately register signals inside and outside the wind farm.

We took pictures of the radar screen with a digital camera (screenshots) every 150 s. Parallel to these, we recorded digital images via a frame grabber onto a PC in two ways – first as a screenshot taken simultaneously with the digital camera screenshots, and secondly an integrated picture was taken every 150 s, overlaying 15 digital images taken every 10 seconds to document all signals and signal tracks of that 150 s period. In addition, signals and their tracks were copied manually onto transparencies fixed to the radar screen.

Data of these recordings – as there are signal altitude and distance - are transferred to databanks. Data correction was applied using the „distance-sampling“ method (BUCKLAND et al. 2001, BSH 2003, 2007).

Visual observations

Visual observations were conducted from sunrise to sunset, 15 min in each 30 min period. Two transects parallel to the vertical radars were observed. One person observed the transect leading into the wind farm, a second person leading away from the wind farm. Visual observations yielded data on numbers and species composition, flight paths and altitudes as well as potential reactions of the birds.

Nocturnal observations

Acoustic surveys were conducted from sunset to sunrise, 10 minutes for each 30 minute period. Recording the birds flight calls yielded again a species composition and an impression of migration intensity. However, since not all birds call during migration and calls can only be heard up to species-specific distances, data gathered from these surveys is biased and limited.

Observation efforts

Observations were conducted during a total of 179 ship days, not accounting for transportation to and from the wind farms (tab. 2).

Table 2: Effective ship days in the years 2005 and 2006

	Horns Rev, North Sea	Nysted, Baltic Sea
spring 2005	9.5	20
autumn 2005	26	27.5
spring 2006	21.5	28
autumn 2006	18.5	28
totals	**75.5**	**103.5**

Results

At the time of this paper, we are reporting exemplary results, as data analyses and assessments have not yet been finalized.

Diurnal observations – species, altitude distribution, avoidance

A total of 114 bird species were recorded at Nysted in the Baltic Sea. Of these, 73 species (64%) were also observed inside the wind farm. At Horns Rev in the North Sea, a total of 99 species were recorded, with 64 (65%) also observed inside the wind farm.

Some species show an apparently marked avoidance of the wind farms. Both the Common Scoter (*Melanitta nigra*) and several goose species (*Anser spec., Branta spec.*) were observed only outside or exclusively above the wind farms for most of the time (fig. 3).

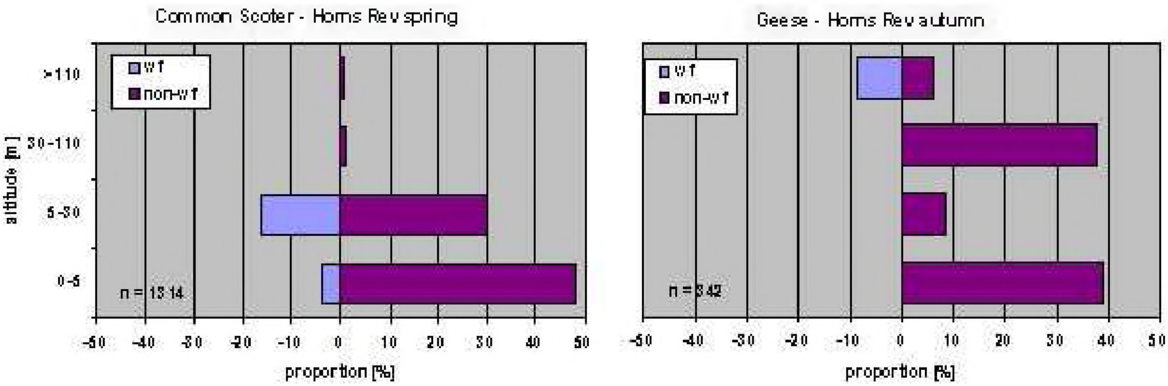

Figure 3: An example of altitude distributions (visual observations) at Horns Rev, North Sea. Altitude classes are: 0-5 m – very low over the water; 5-30 m – below rotor blades; 30-110 m – within the rotor area; > 110 m – above the rotor area.

Other species, however, showed less avoidance of the wind farm areas. These include most of the gull species, such as the herring gull (*Larus argentatus*) and the common gull (*Larus canus*), which have been present over longer time periods at the sites. There seems to be no avoidance of the wind farm at all, and also the altitude class of the "within the rotor areas" has been frequently used. On the other hand, the little gull (Larus minutus), a non-resident migrating species which has been observed at Horns Rev, showed a distinct but not complete avoidance of the wind farms in both migrating and feeding patterns (fig. 4).

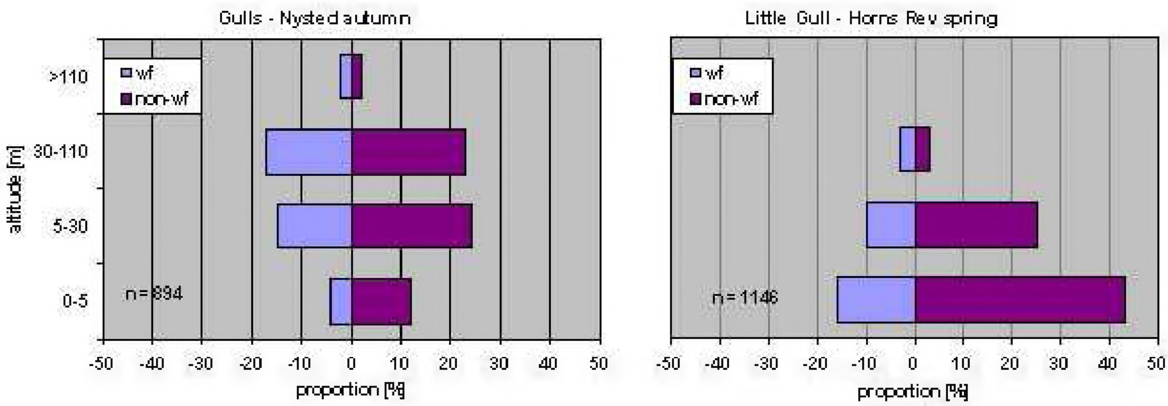

Figure 4: Examples of altitude distributions of gulls in both wind farms. Legend see fig. 3.

Another example are raptors, which also migrate across the sea within the wind farm areas. A total of 185 individuals of 14 raptor species has been observed at both wind farms. Of those, at least 88 individuals have been recorded flying within or above the wind farms. For the sparrowhawk (*Accipiter nisus*), we have enough observations to analyze both the altitude distribution and the reactions. The latter can only be listed for a selection of individuals which have been observed more intensively. Reactions are most frequently avoidance reactions in short to medium distances, leading to the conclusion that the bird either does not enter the wind farm areas or that the bird adjusts its flight path such that it keeps a certain distance to the individual wind mills (fig. 5).

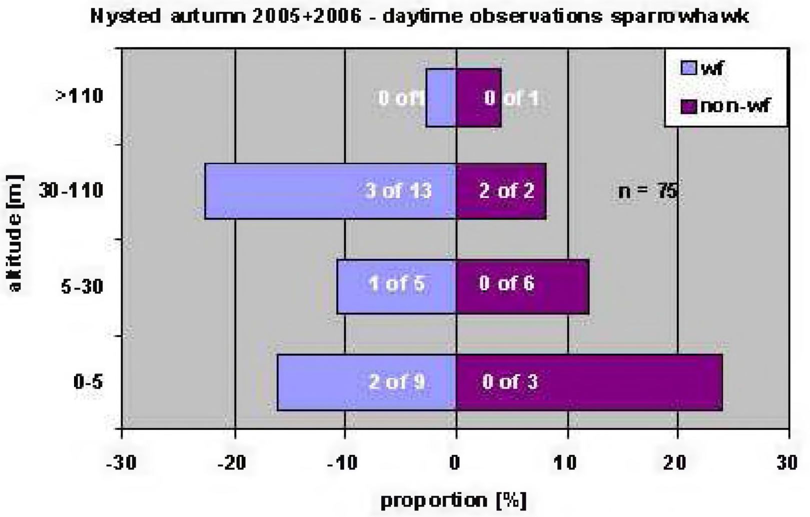

Figure 5: Altitude distributions and reactions for the sparrowhawk at Nysted, Baltic Sea. Legend s. fig. 3. White letters denote the number of reacting birds (see text for details).

Radar observations – diurnal and nocturnal altitude distribution

Radar data of the ranges 500 m and 1,500 m will be analysed and presented separately. In order to take into account that fact that bird migration concentrates during certain time periods dependent on long and short-term weather situations, we present data from the 5 days/nights with the most intense migration as well as data for the rest of the observation period. In the example of data collected for autumn at Nysted in the Baltic Sea, it becomes evident that during nights of intense migration the altitude distribution is clearly pushed towards the higher altitudes. This means that less birds are recorded in the lower altitude classes. During times of high migration intensity, only 25% of the signals were recorded within the risk area of altitudes below 200 m (wind mills have an altitude of 110 m including rotor blades), and only 13-14% below 100 m. During the other time periods, 46% of the signals are below 200 m during the daytime, and 41% during the night. Likewise, 34% are below 100 m during the daytime and 23% during the night (fig. 6 and 7).

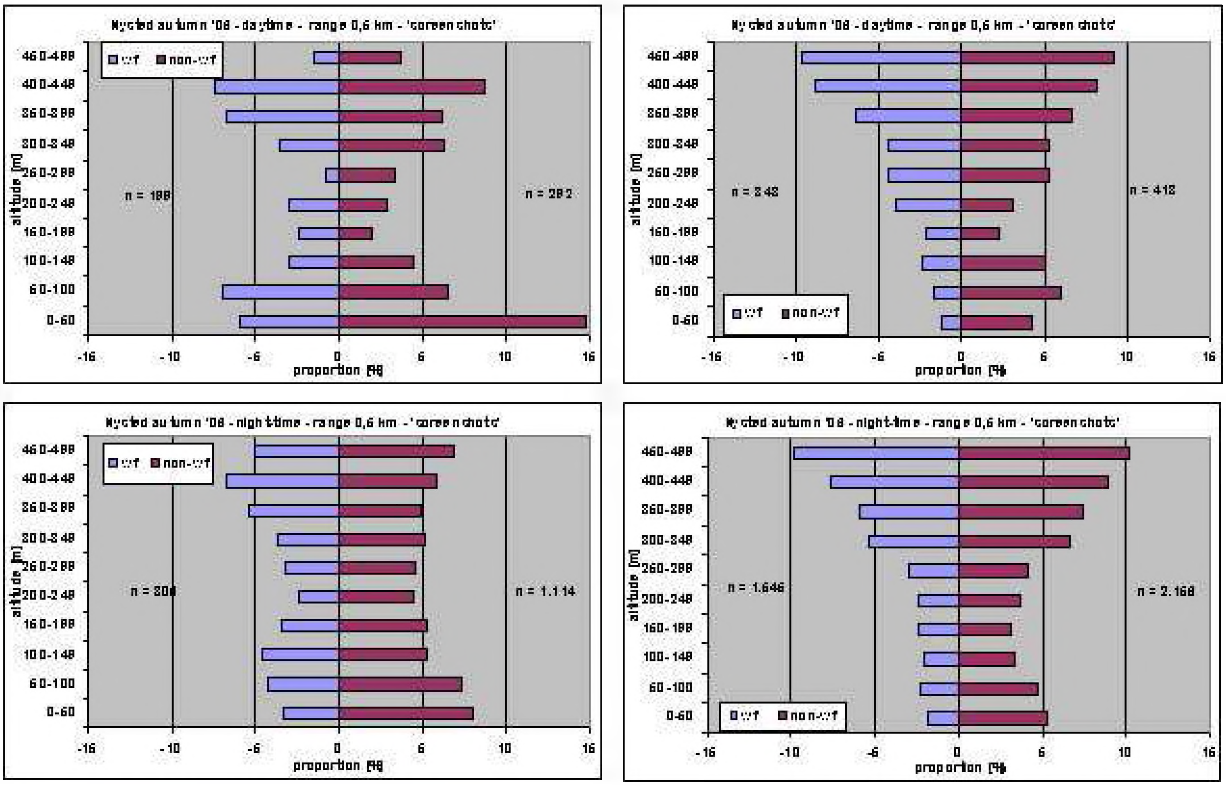

Figure 6: Altitude distributions for Nysted, Baltic Sea; range 500 m. Left: low migration intensity; Right: high migration intensity; Top: daytime; Bottom: night-time.

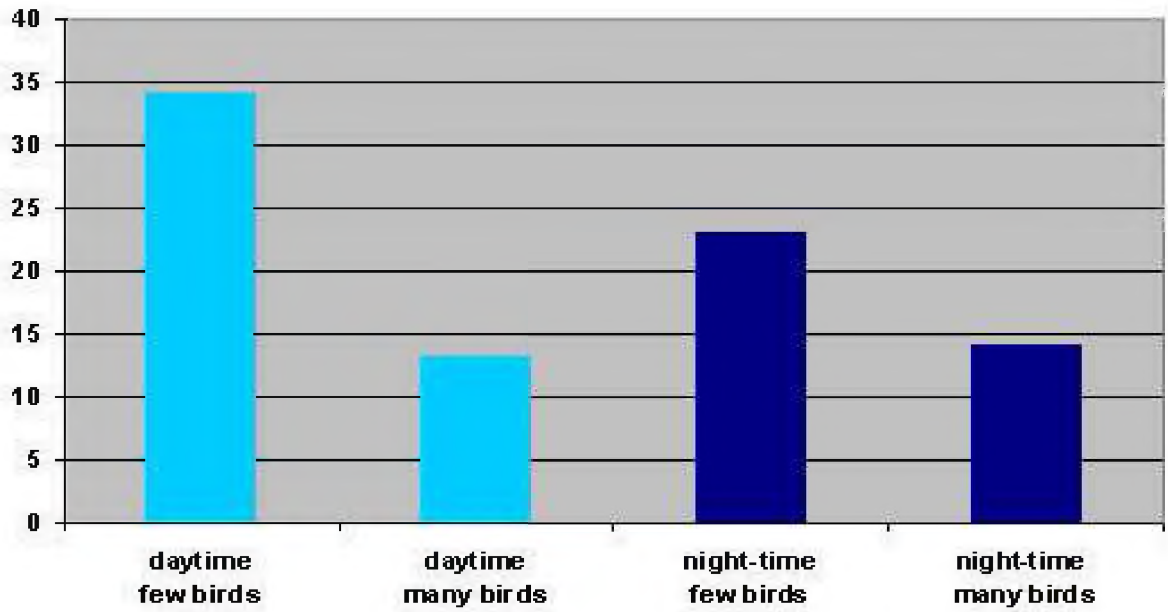

Figure 7: Signals below 100 m in days and nights with different migration intensities (Nysted, Baltic Sea, autumn). Data for the range of 500 m.

Analyzing the range of 1,500 m, one can see that generally during all time periods, but especially during times of intensive migration, a large percentage of birds is recorded far above 500 m. During low migration intensity, only 50% of the signals are above 500 m, during high migration intensity this value is 85-90% (fig. 8).

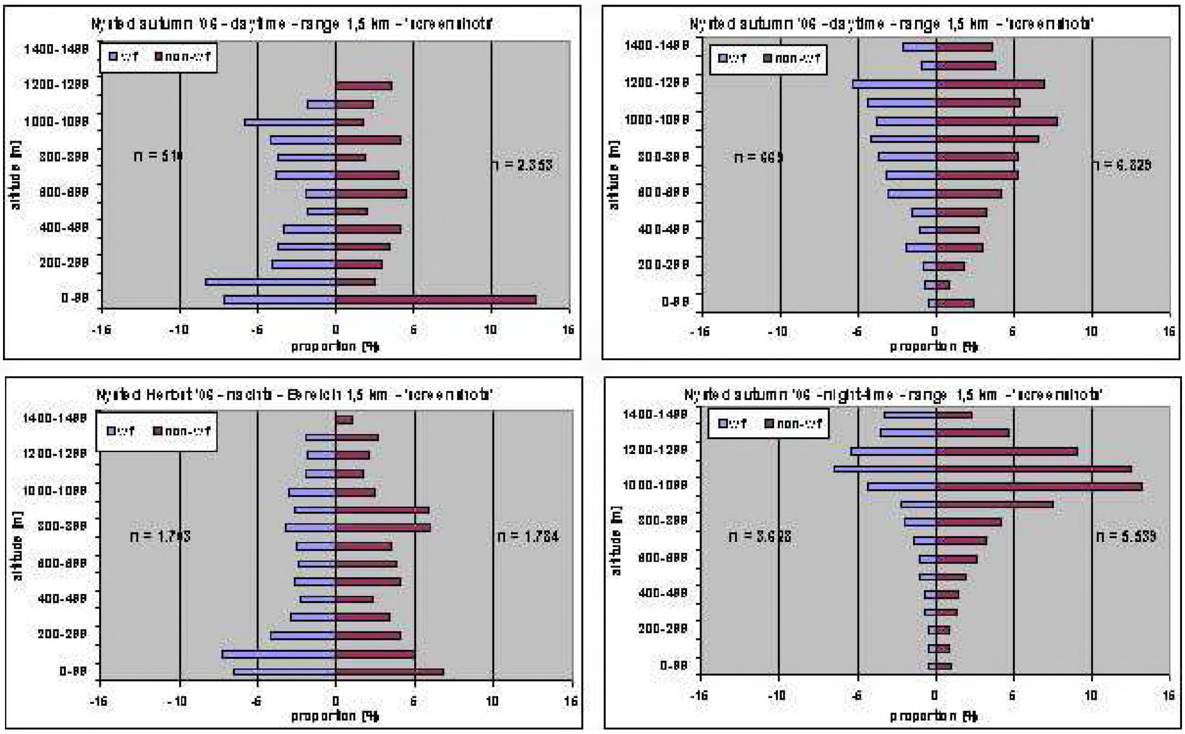

Figure 8: Altitude distributions for Nysted, Baltic Sea; range 1500 m. Left: low migration intensity; Right: high migration intensity; Top: daytime; Bottom: night-time.

Discussion

The goal of these investigations is to collect and analyze data in order to further assess the collision risk of birds in offshore wind farms. These studies complement Danish studies based on platforms on land at some distance from offshore wind farms, concentrating on seabirds and duck species (for an overview see PETERSEN et al. 2006). A further goal is to collect data on smaller birds as well as to differentiate altitude distributions inside and outside the wind farms. The only possibility is to do ship-based observations. In this way, one can be in the direct vicinity of the wind farms and be flexible with regard to the positions in relation to bird migration directions. Presented here are the results of visual and radar observations. Results allow conclusions on species composition, altitude distributions inside and outside the wind farms and potential reactions of birds to the wind farms. Further analyses will yield altitude changes of birds approaching the wind farm during the day and night.

Species seem to avoid the wind farm areas during migration, whereas resident, non-migrating species or species spending extended time periods in the area (non-breeding, staging and overwintering) use areas inside the wind farms. This is a phenomenon also known from other studies (e.g. KRIJGSVELD et al. 2005). Especially at Nysted in the Baltic Sea, large groups of great cormorant (*Phalocrocorax carbo sinensis*) have been observed performing collective hunts inside the wind farms. In addition, cormorants have been observed resting on the meteorological masts or the wind mill structures during their hunts or flights to and from their roosts. Several gull species have been recorded during daytime in and around the wind farms. Consequently, a barrier effect exists for species that avoid wind farms on a large scale, while the collision risk is increased for species using the wind farm area (GARTHE & HÜPPOP 2004, GRÜNKORN et al. 2005).

Migrating raptors that are flying towards the wind farm generally fly through the wind farms. However, in many cases they adapt their flight paths in order to avoid collision with or even come too close to the wind mills. For smaller birds, namely passerines, it is difficult to quantify flight paths, altitudes or reactions with daytime observations, as those species may be sighted only in close proximity to the observation ships, and rarely can be followed beyond the border of the wind farm.

Bird migration, and above all songbird migration, is concentrated during a few time periods which depend on short and long-term weather situations. Bird species cannot be identified by the surveillance radar used. Consequently, an analysis of the most intensive migration period assures that songbird migration dominates, and that potential collision is more likely to occur at these times than during times of low migration intensity. It turns out that during high migration intensity less birds migrate within the risk areas (altitude category below 100 m).

Analyses will be continued and will finally describe altitude distributions inside and outside the wind farms at both locations during times of different migration intensities and weather situations. Analysis of flight paths recorded with the vertical radar will yield potential altitude changes of birds flying towards the wind farms. Together with the results of the daytime observations, more data will be available to further investigate and describe collision risk models for different bird taxa. However, only a successful cooperation between the research groups working on these issues will help to better integrate and understand the issue of the birds collision risks at sea.

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Offshore Wind Farms – Disturbance or attraction for harbour porpoises
T-POD investigations in Horns Rev and Nysted

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Abstract

This study investigates the effects of an operating offshore wind farm on the temporal and spatial pattern of harbour porpoise acoustic activity at a fine scale. The project was conducted jointly by the University of Hamburg and BioConsult SH in the two Danish offshore wind farms Horns Rev (North Sea) and Nysted (Baltic Sea) and financed by the German Federal Ministry for the Environment. Data were collected between June 2005 and November 2006.

The study underlines that static acoustic monitoring with T-PODs is a powerful tool to investigate offshore wind farm impacts on harbour porpoises. T-POD data show an almost daily presence of harbour porpoises in the two wind farm areas Horns Rev and Nysted. The times with echolocation activity and thus the presence of harbour porpoises were significantly higher in the North Sea. This corresponds to different densities revealed by aerial surveys covering both bodies of water (SIEBERT et al. 2006).

Both areas show a distinct seasonal click activity pattern with peaks in summer and low values in winter. The fine-scaled spatial approach revealed a stronger difference in harbour porpoise echolocation signals between different rows of T-PODs separated by a few kilometres, than differences within one row comparing areas inside and outside the wind farm. Because no directional trend in the difference of porpoise activity between the areas inside and outside the wind farm could be recorded, an influence of the wind farm on harbour porpoise presence could not be detected.

Echolocation activity differed between day and night and in relation to the position to the wind farm. In 2005, the diurnal activity pattern corresponded to results of a fish survey, with higher fish density during the night inside the wind farm.

A first investigation of click-train structures indicates different feeding behaviour of harbour porpoises in Nysted and Horns Rev.

In summer 2006, maintenance procedures made it necessary to shut the Nysted wind farm down for an entire week. This shut-off did not show any effect on the presence or absence of the species.

Introduction

The expansion of offshore wind farms in German waters is planned with the background goal of reducing CO_2 output. 15 licences for wind farms in the North Sea and 3 licences for wind farms in the Baltic Sea have been made available since 2002 (BSH 2007).

Harbour porpoises regularly occur in both German Seas. The influence of wind farms on these animals is part of a controversial discussion. Basically, three negative effects of offshore wind farms on harbour porpoises are suspected:

1. Direct habitat loss,

2. Displacement by noise emissions,
3. Displacement by additional service operations and traffic.

On the other hand, it is possible that a wind farm may attract porpoises due to a higher density of prey, as fishing is prohibited inside the wind farm area and artificial reefs. Theoretical considerations about noise emissions, sound intensity and auditory sensitivity of harbour porpoises conclude that the audibility of offshore wind energy turbines reaches up to several hundred meters (MADSEN et al. 2006). A reaction is therefore only expected in the direct surrounding of the turbines. Results of operating wind farms in Denmark show occurrences of harbour porpoises even after the construction of wind farms within the area of the wind farm (no complete avoidance TOUGAARD et al. 2006a, 2006b). Whereas significantly fewer harbour porpoises have been registered to occur in the area of the offshore wind farm Nysted (Baltic Sea) during its operation than before the plant's development, no clear effects on the porpoise population could be determined in a before and after comparison for the offshore wind farm Horns Rev in the North Sea. Because the focal question arises as to how offshore wind energy turbines may influence harbour porpoises during the expansion and development of this technology in German waters, the Federal Ministry for the Environment commissioned the study presented in the following pages.

The main objective of this study, which was carried out by the University of Hamburg in cooperation with BioConsult SH, is the review of potential effects of offshore wind farms in the areas surrounding wind farms and/or single turbines. The following questions are handled:

- Do small-scale differences exist between the presence / absence of harbour porpoises between areas inside and outside wind farms?
- Do small-scale differences exist in the behaviour of harbour porpoises inside and outside wind farms?
- Can wind farms cause potential differences?
- Which role do different factors, such as water depth, topography of the seabed, noise from ships, etc. play?

To answer these questions, we used a passive acoustic monitoring method, consisting of so called „T-PODs“ (Timing Porpoise Detector). These devices continually record and save the high frequency echolocation sounds of harbour porpoises with a hydrophone and filters. The data investigation lasted from June 2005 until November 2006.

Method

Areas of investigation

The investigations were done in both Danish offshore wind farms Horns Rev (North Sea) and Nysted (Baltic Sea) (fig. 1). The wind farm Horns Rev began operation in 2002, Nysted in 2003.

Figure 1: Position of the investigation areas Horns Rev (North Sea) and Nysted (Baltic Sea).

The T-POD

Harbour porpoises orientate themselves under water with short high frequency echolocation clicks. They send out audible clicks and are able to appraise the environment and detect prey with help of subsequent echoes (echolocation). The T-POD takes advantage of this behaviour. The clicks can be recorded with help of a hydrophone and after presetting different filters, the clicks can be transformed into digital data and saved. The T-POD is housed in a 70 cm long PVC pipe, with an external hydrophone on one end and a lid screwed on the other. The pipe is equipped with a 128 MB non-volatile memory, with two bundles of six 1.5 volt D-cell alkaline batteries and a USB port for data transfer with a PC. The battery voltage lasts for about 8 weeks. The sensitivity of the filter and its bandwidth can be individually set for each device. All devices were equally set within this investigation. An important precondition for the comparison of data from different devices is the same sensitivity of the devices. Therefore all used PODs were calibrated in a test tank as well as outdoors. The signals are recorded in real time, so that it is possible to identify „trains“ due to a temporal resolution of clicks. Raw data can be read by the corresponding software, „TPOD.exe“, and checked against the probability of real porpoise clicks with the help of a programmed algorithm. The algorithm scans for series of clicks with certain distinctive patterns and classifies them in four different probability categories. Only the two highest categories were used („CetAll“) for further analysis. Gathered data is saved and analysed in an Access-database. The main parameter for analysis is the so-called porpoise positive time per time unit (mostly porpoise-positive 10 minute blocks per day). This parameter is used to measure the presence of harbour porpoises within the measurement range of each T-POD.

The T-PODs were installed with an easily retrievable two-anchor system, in which they were placed two meters above the seabed with the upward opening angle of the hydrophone pointing towards the open water column.

Study design

The study design was chosen so that in each case 10 T-PODS were installed in each wind farm at the same time. Respectively, 5 devices were fastened in a row with a distance of 600 m to each other. Two devices of one row were placed outside the wind farm up to a maximum distance of around 1,400 m to the next wind turbine. Two of the three devices within the wind farm were placed next to a wind turbine (around 150 m).

In the first analysis we compared the medium „porpoise positive time“ in one row with the results of a second row that was installed at the same time but at some kilometres distance. It was so tested to determine whether small-scale differences of the presence of harbour porpoises within the wind farm area of 16 to 20 km^2 could be assessed.

In a second step, the results of the two devices of a row located outside of the wind farm were averaged. These averages were compared to the ones of the devices of the row that was located mostly inside (comparison between inside and outside of the wind farm).

To minimize the influence of small-scale differences of the habitat and of the topography, each row was seen as a single experiment and around every 8 weeks the rows were changed. The results presented here refer mainly to the offshore wind farm Nysted.

Results and discussion

We changed the rows four times in the area of the offshore wind farm Nysted. A total of 10 different row experiments were done (fig. 2). The survey started in the middle of June 2005. The T-PODs recorded a sum of 1,627 days. Data of 1,964 days were collected between the beginning of March and the beginning of November 2006.

Data gathered from the offshore wind farm Horns Rev turned was approximately 40% less because of background noise – possibly caused by sand movements during extremely windy weather conditions. But even there 10 different row experiments could be carried out here.

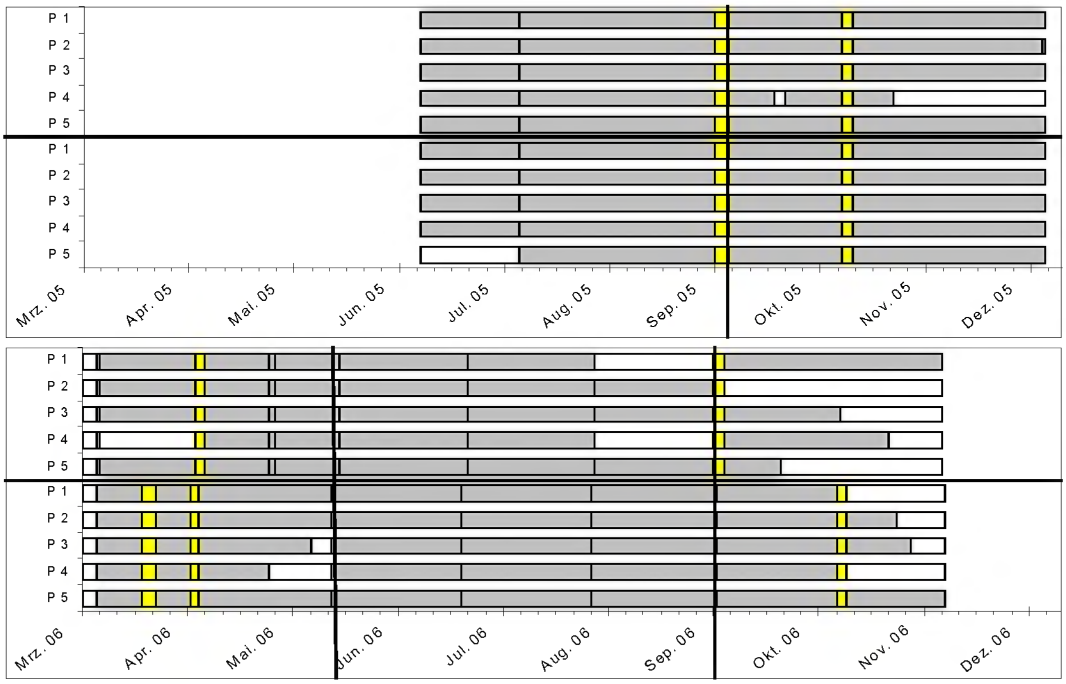

Figure 2: Recorded data of PODs in the years 2005 (above) and 2006 (below) placed in the offshore wind farm Nysted. P1-P3 = within the offshore wind farm; P4, P5 = outside of the offshore wind farm. Vertical black lines show changes of rows. Grey bars: gathered POD-data; white bar: no data; yellow bar: outdoor calibration.

Comparison North Sea – Baltic Sea

The first analysis of „porpoise positive time“ as the parameter for the presence of harbour porpoises shows that the T-PODs recorded harbour porpoises nearly daily in both areas of the wind farms (fig. 3). If the temporal solution of days is elevated to the smallest analysed unit of minutes, it can be seen that the devices recorded harbour porpoises nearly daily but that the presence of the animals within the investigation area of the PODs was on average very short. In the offshore wind farm Nysted, harbour porpoises were recorded with an average time of 4.8 per 7 hours per day. In comparison, harbour porpoises were registered in the North Sea more often. In an average of 13 hours they were recorded with an average time of 6.5 minutes per hour.

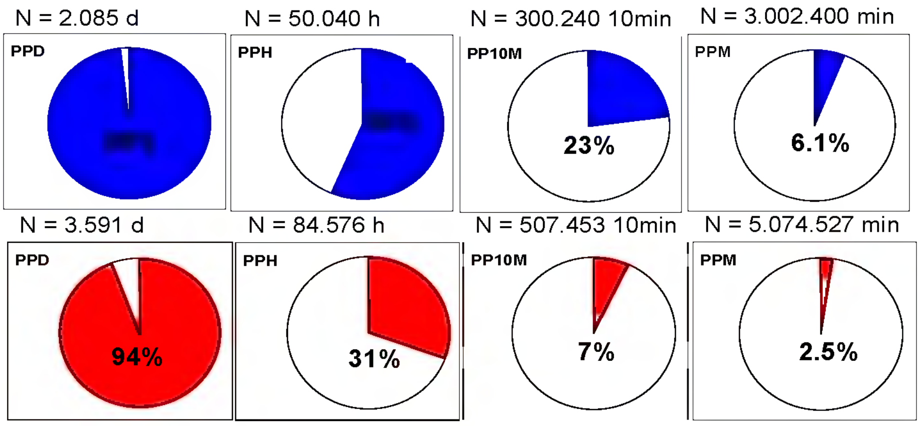

Figure 3: Sum of "porpoise positive time" of all devices for different time units in the offshore wind farm Nysted (above) and Horns Rev (below).

The parameter „porpoise positive 10minutes per day" is used in the following analyses. It is a good compromise between a temporally high-scaled resolution and an adequate scale to avoid blur caused by small differences of sensitivity of the different devices.

Seasonality

The temporal distribution of the recorded patterns of presence of harbour porpoises shows clear seasonal effects within the wind farms (fig. 4). Not only seasonal differences with a maximum in summer and a minimum in autumn/winter but also differences between years of observance can be shown. In July 2005 as well as in October 2005 the highest number of harbour porpoise contacts were measured in the area of the offshore wind farm Nysted. But in the following year only a maximum of the population was measured in July (fig. 5).

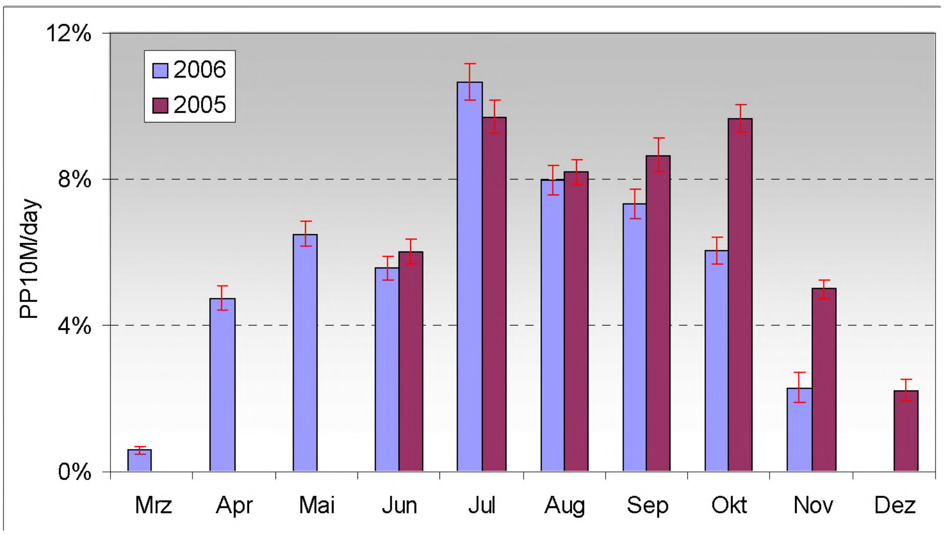

Figure 4: Monthly presence of harbour porpoises in the investigation area of the offshore wind farm Nysted in 2005 and 2006 (mean „porpoise positive 10minutes/day" per month of all devices, ± SE)

Spatial differences

The five comparisons of the two simultaneously installed rows showed significant differences concerning the average periods of presence in four experiments (fig. 5). The two rows varied maximally in factor 2 (May-Sep. 2006).

This difference between the areas, which were over three to eight kilometres apart, was significantly stronger than the variation between inside and outside areas of the wind farm within one row (fig. 5). Latter comparison indicates no explicit trend: Within four of ten rows, significantly more time intervals with sounds by harbour porpoises were measured outside of the wind farm. In the two rows that registered the most porpoise clicks, a (small) significant effect with a higher activity within the wind farm was determined. No difference between inside and outside areas of the wind farm was found within four rows.

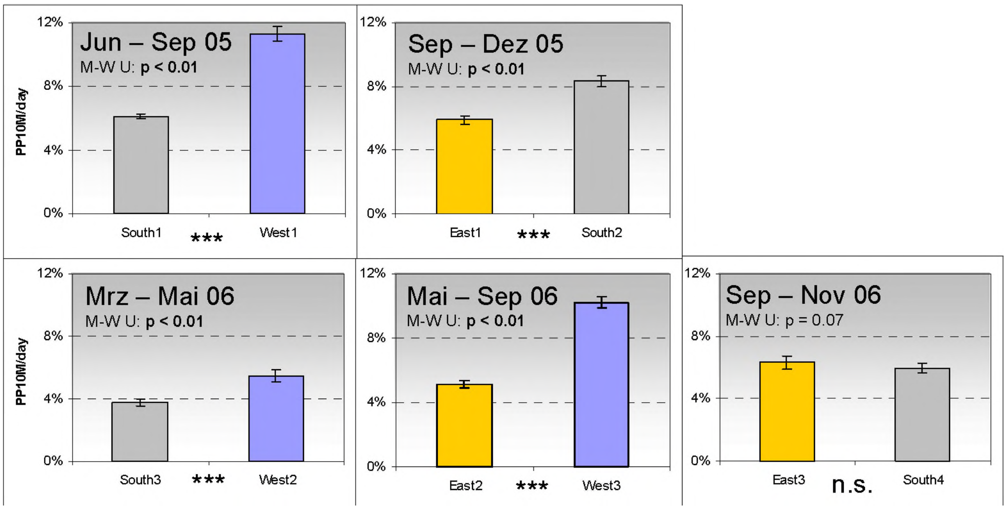

Figure 5: Presence of harbour porpoises in different rows that were installed in the offshore wind farm Nysted at the same time (mean values „porpoise positive 10minutes/day per measuring time; ± SE).

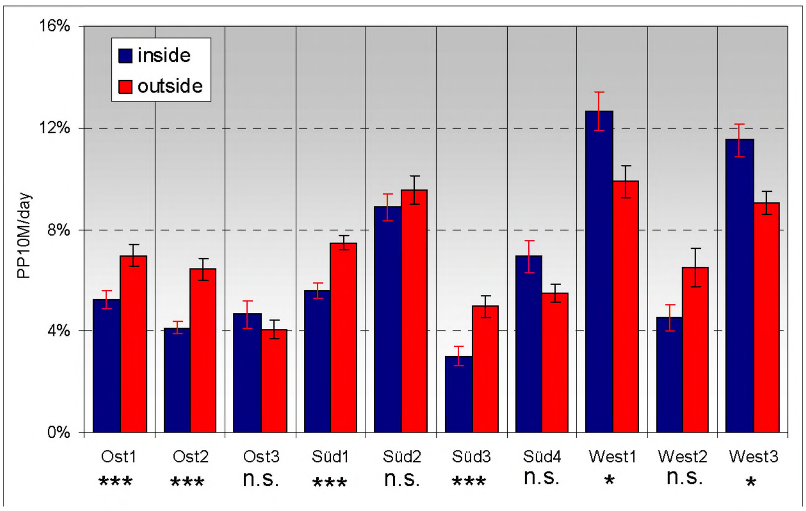

Figure 6: Presence of harbour porpoises inside and outside of the wind farm for 10 different rows within offshore wind farm Nysted (mean values „porpoise positive 10minutes/day per measuring time; ± SE).

Effects of temporary turbine standstill

Between June 25 and July 2, 2006 work all turbines in the offshore wind farm Nysted were temporarily shut down due to maintenance. This special case was assessed for possible changes of presence of harbour porpoises within the wind farm area. In the week of the shut down, the mean presence of harbour porpoises was determined and the results were compared to the weeks before and after (fig. 7). The result shows that the weeks of standstill had no apparent influence on the presence of harbour porpoises. An assumed negative effect in row west (fig. 7 below left) inside of the wind farm cannot be found in row east. Four weeks before, as well as five weeks after, similar low presences of harbour porpoises were measured. Such an effect, which could be expected by e.g. traffic of service ships, cannot be detected. Furthermore, because the traffic of service ships did not differ from the ordinary traffic of service (two installation ships per day), an effect can be excluded. Investigations of further days of turbine standstill are needed here.

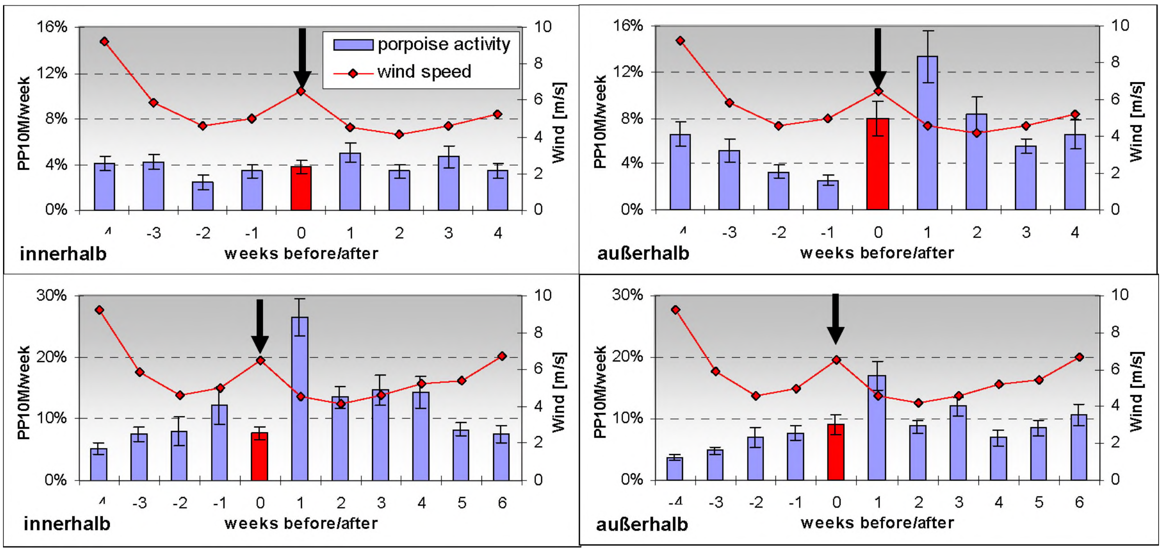

Figure 7: Presence of harbour porpoises inside and outside of the offshore wind farm Nysted in the rows east (above) and west (below) in different weeks before and after the shut down of turbines (arrow). The red line additionally shows the mean wind speed for the relevant week.

Diurnal differences

For each row a 24-hour-rythm in presence of harbour porpoises was assessed on the basis of „porpoise positive minutes per hour in the day“ (fig. 8). In summer 2005 a clear day-night-rhythm with high activity during the night and low activity during the day turned out in the offshore wind farm Nysted. This pattern was only noticeable inside of the wind farm but was not noticeable outside the wind farm fig. 8).

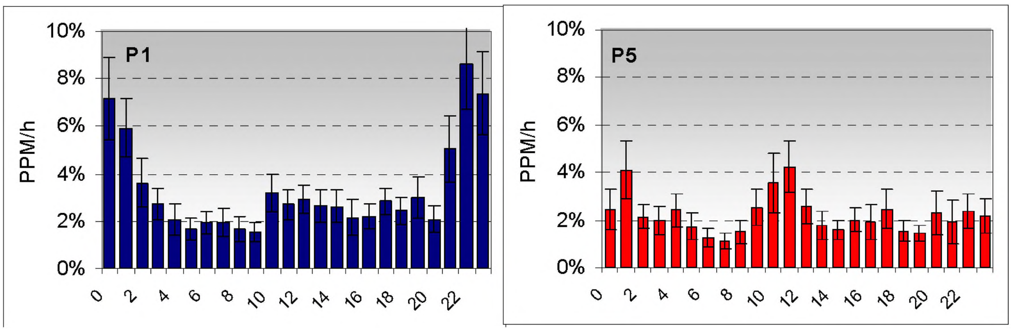

Figure 8: Mean presence of harbour porpoises in the course of a 24-hour day between June and September 2005 inside (left) of offshore wind farm Nysted and outside (right).

Such a pattern was clearly observable in summer 2006 but it was spatially recognizable with significantly high activity at night outside the wind farm and with no pattern inside. The pattern identified in 2005 could be consistent with the results of Danish researchers. They observed in 2005 a higher density of fish in the water column inside of the wind farm at night (LEONHARD et al. 2006). No parallel observations of fish were available for 2006, so that an interpretation of the result without another analysis of data remains inconclusive.

Behaviour

The analysis of data with high temporal resolution makes it possible to identify special click patterns additional to the patterns of presence. These possibly admit conclusions to certain behaviour. According to BUSNEL & DZIEDZIC (1967) the click sequences during foraging are shaped by a medium interval of noise between the clicks of about 40 ms with an abrupt and rapid decrease to 10 ms (up to 2 ms) (“feeding buzz”). This typical pattern of noise can be recognized by the T-POD data.

In a first approach, we defined the part of the click series via an enquiry of a database. These had a click interval between two clicks that were shorter than 10ms and that could be part of a „feeding buzz“. The result of this analysis showed a significant difference between the areas of Horns Rev and Nysted. In Nysted the part of such click series on an average of 12% and over a 24-hour day showed no pattern. In Horns Rev, in contrast, the part of the click series with a short click interval is higher than 30% at night and decreases during the day down to 10%. This pattern indicates a different behaviour of foraging within a day and needs further analysis.

Conclusion

The presented study emphasizes the suitability of the passive acoustic monitoring as an informative instrument to analyse questions about the influence of wind energy turbines on harbour porpoises. The results show that harbour porpoises occur in the two areas of Horns Rev (North Sea) and Nysted (Baltic Sea) nearly daily and that they were recorded by T-PODS. Although a significant difference between the marine areas regarding the number of occurring harbour porpoises was detected with a high rate of harbour porpoise contacts in the North Sea. This result corresponds with aerial surveys that observed the density of harbour porpoises in both seas (SIEBERT et al. 2006).

In both areas a clear seasonal pattern was observed with a maximum in summer and minimum in winter. The differences in presence of harbour porpoises inside of the whole area of the wind farm was higher between two areas that were spatially separated through some kilometres than the difference in a T-POD row between inside and outside areas of the wind farm. Referring to this, no consistent trend was observed so that no significant influence of the wind farm on the occurrence of harbour porpoises can be seen.

The shut down of all turbines in the offshore wind farm Nysted had no effect on the presence of harbour porpoises.

Clear differences of activity of harbour porpoises were detected between day and night. These were different depending on the position of the T-PODs to the wind farm and in 2005 they were consistent with surveys about the occurrence of fish within the area of the wind farm.

First analyses of the “clicktrain – structures” show a different behaviour of harbour porpoises in Nysted and Horns Rev.

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Noise emissions during pile driving of offshore foundations

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Abstract

Considerable noise emissions occur as a result of the operation and in particular the construction of offshore wind turbines. This noise has possible effects on marine life. With the help of reliable thresholds, assessments, forecast models of underwater noise from offshore wind farms and noise reducing methods, the possible damage and disturbance of marine life from underwater noise emissions during the operation and construction of offshore wind turbines should be avoided.

Common foundation techniques include the ramming of steel piles up to 30 m into the seabed. In general, hydraulic pile drivers are used for this purpose. During the erection of a 3.5 m monopile, peak sound pressure levels of more than 200 dB and single event levels of 174 dB SEL have been measured at 750 m distance from the pile driver.

These levels are potentially harmful to marine mammals like harbour porpoises and induce escape reactions across a large area. Due to larger piles requiring higher blow energies, even higher levels are expected in future projects. Hence, noise reduction methods are necessary to keep the BSH standard level of 160 dB SEL re 1 µPa at 750 m distance.

Within a joint research project, a concept of noise reducing methods has been derived from measured results and numerical simulations on the construction noise of offshore wind turbines. Theoretical background and technical realizations are discussed in this paper. Furthermore, results of numerical simulations and of scaled and near full scale experiments are shown.

There are two main approaches:

1. Adjusting the parameters of the pile ramming as primary mitigation methods,

2. Use of sound barriers as secondary methods.

One of the key parameters of method 1 is ramming duration. Prolonging the impulse not only reduces the sound level, but also shifts the maximum of the acoustic spectrum to lower frequencies, which are less harmful to marine mammals.

Vibration pile driving, where applicable, also considerably reduces the sound level with respect to impulse pile driving, in particular the peak level. Underwater noise measurements of vibro-hammer are compared to those of an impulse hammer.

The second method includes various techniques like the well-known bubble curtain and other noise-blanketing techniques, which make the most of sound impedance between the barrier material, air and water.

Both method 1 and 2 are mutually independent. When used in combination, their efficiency simply adds up in terms of dB numbers and a very high degree of noise reduction is achieved.

The research project is supported by the German Federal Ministry for the Environment.

Introduction

The Institute for Structural Analysis (ISD) of the Leibniz University of Hannover, the German Wind Energy Institute (DEWI) in Wilhelmshaven, and the Institute for Technical and Applied Physics (itap) in Oldenburg are partners in the on-going project, 'Standard Procedures for the Determination and Assessment of Noise Impact on Sea Life by Offshore Wind Farms' which is funded by the German Federal Ministry for the Environment (BMU).

The aim of this project is to determine the impact area of influence of offshore wind farms, to allow the formulation of recommendations for acoustic emission thresholds of offshore wind farms in cooperation with biologists, to study the generation, radiation and attenuation of underwater noise and to derive a concept of noise reduction methods during pile driving of offshore foundations.

The operation and in particular the construction of offshore wind energy turbines (fig.1) induce considerable underwater noise emissions. Extensive measurements and numerical simulations of monopiles and jacket foundations under construction result in maximum underwater sound pressure levels of more than 200 dB re 1 μPa nearby during pile driving and in considerable noise levels several tens of kilometres away. This noise has possible effects on marine life, but up to now not known enough to be able to formulate exact acoustic emission limits and assessment procedures.

It is assumed that harbour porpoises and seals can be affected by noises from machines and vessels, piling and installation of the wind turbines.

The immission value limit of 160 dB (SEL) at 750 m derived from audiograms of harbour porpoises results from cooperative research with biologists.

Figure 1: Hydraulic hammer on a pile of FINO1

Measured underwater noise emissions

Piling, in particular the use of hydraulic hammers, creates high frequency noise with considerable underwater sound levels.

Impulse noise, such as pile driving noise, is described by two sound levels. The first level is the *peak level*,

$$L_{peak} = 20 \log_{10} (| p_{peak} | / p_0),$$

where p_{peak} is the maximum positive or negative sound pressure observed and p_0 is 1 µPa .

The second quantity for describing pile driving noise is the *single event sound pressure level* L_E (sometimes also abbreviated SEL), which is basically normalized to 1 second:

$$L_E = 10 \log \left(\frac{1}{T_0} \int_{t1}^{t2} \frac{p(t)^2}{p_0^2} dt \right)$$

The time interval T_0 is set to 1 s.

Fig. 2 shows the underwater sound pressure of a single stroke of a hydraulic hammer, measured at a distance of 1.6 km.

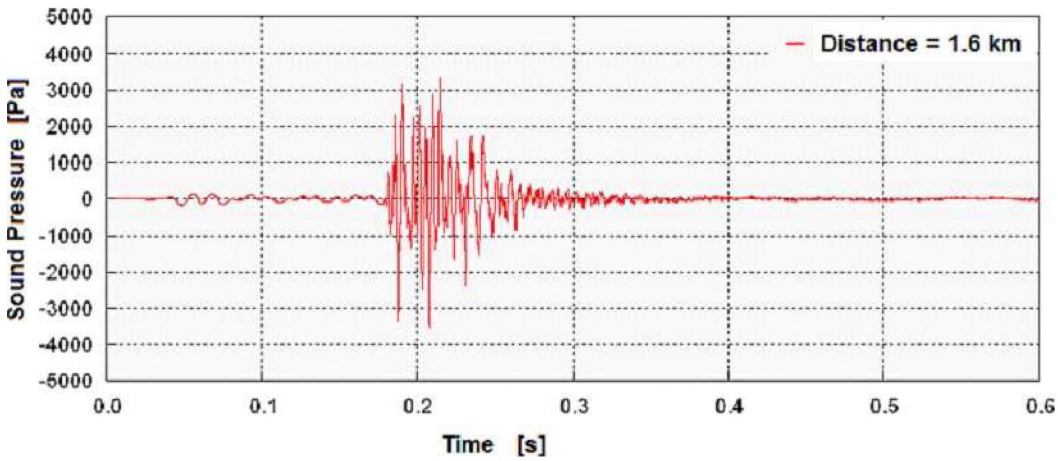

Figure 2: Measured sound pressure of a single stroke

The contact time of a hydraulic hammer is 4 ms and the signal length of the resulting sound radiated from the vibrating pile takes about 200 ms.

This single sound event in fig. 2 exhibits a maximum peak sound pressure of about:

$$p_{peak} = 3500 \text{ Pa},$$

leading to the logarithmic *peak sound pressure level* of:

$$L_{peak} = 191 \text{ dB re } 1\mu\text{Pa},$$

and to the *single event sound pressure level* (as an equivalent energy level) of:

$$L_E = 167 \text{ dB re } 1\mu\text{Pa}.$$

The underwater noise emissions of offshore pile driving during construction of different objects in table 1 are measured at a distance of about 750 m.

Table 1: Measured pile driving underwater noise emissions at a distance of 750 m

Measured Noise Emissions:				
Object	**Pile diam. [m]**	**Energy [kNm]**	**Lpeak [dB]**	**LE [dB]**
Port construction, coast	1.5	280	184	158
Monopile Sky2000, Baltic S.	3.0	280	185	164
FINO1 (Jacket), North Sea	1.5	280	189	164
FINO2 (Monopile), Ostsee	3.4	500	189	169
Monopile Amrumbank, N.Sea 3.5	800	200	175	
5 MW – OWEC (expected)	6.0	1600	>205	>178

Peak sound pressure levels of:

$$L_{peak} > 180 \text{ dB re } 1\mu\text{Pa}$$

and single event sound levels of:

$$L_E > 160 \text{ dB re } 1\mu\text{Pa}$$

are potentially harmful to marine mammals and other marine animals.

In Germany, several large offshore wind farms with several hundred turbines of about 5 MW are planned in the North Sea and the Baltic Sea. This increase in installed power per unit is accompanied by an increase of the expected construction noise from pile driving.

Because of the high hydro acoustic levels, a concept of reasonable noise reduction methods is derived from measured results and numerical simulations on construction noise of offshore wind turbines.

General aspects of noise reduction methods

Only a very small amount of the impact energy of a hydraulic hammer is radiated directly into water as hydro sound (fig. 3).

Yet this small amount of energy is responsible for the very high hydro sound levels. Most of the energy is driven into the ground and vanishes by dissipation.

Energy transfer from the ground into the water is possible, mainly from dense soil material and mainly near the location of pile driving. In general and in long distances, this noise is less important than the noise directly radiated from the pile.

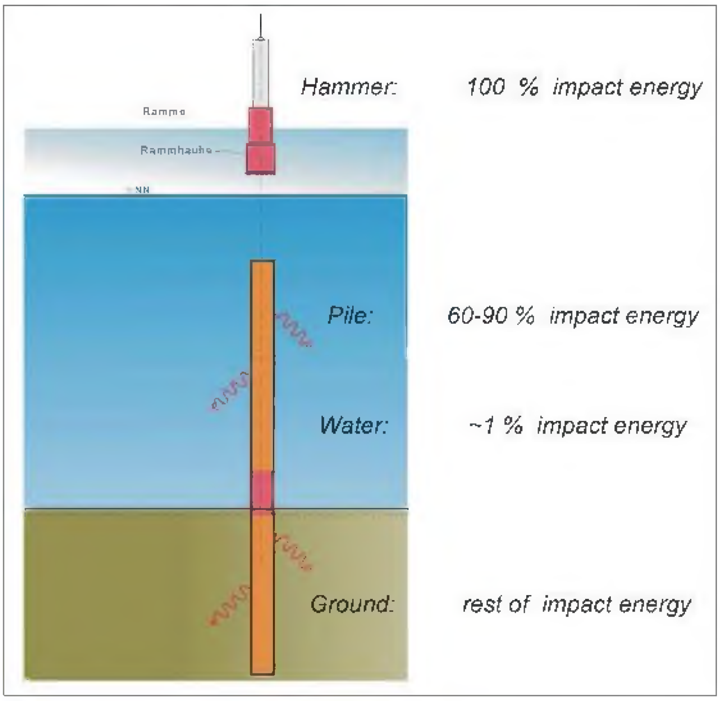

Figure 3: Balance of the whole ram energy.

There are two main approaches to noise reduction methods of construction noise:

1. Primary noise reduction methods by changing the excitation (active method) such as:
   - Adjusting the parameters of the pile stroke and prolonging the impulse contact time;
   - Using vibrators for small piles instead of impact hammers.
2. Secondary noise reduction methods with changing the transmission path (passive method) include:
   - Using a curtain of air bubbles around the pile;
   - Using a foam coated tube as a noise barrier over the pile.

Prolonging the impulse contact time

Numerical FE-simulations in fig. 4 show that the radiated hydrodynamic sound pressure depends on the velocity of lateral pile vibrations.

Using the same pile driving energy while prolonging the contact time of the hydraulic hammer (fig. 5) results in smaller impact forces and thus generates smaller velocity amplitudes of pile vibrations.

The extension of the pulse duration from 4 ms to 8 ms, for example by inserting a "soft" layer between pulse hammer and pile, leads to about 9 dB noise reduction of the sound level:

- 3 dB, as smaller impact forces generate smaller velocity amplitudes, and additional
- 6 dB, as longer contact times result in lower frequencies and smaller velocity amplitudes.

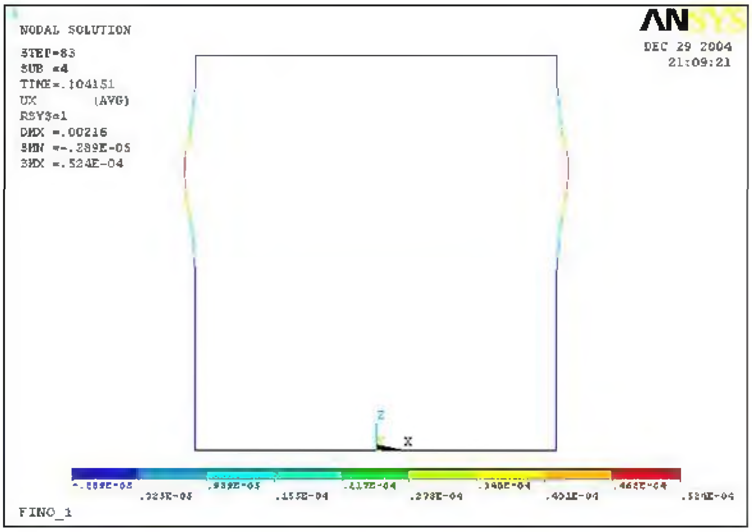

Figure 4: Velocity amplitudes of pile vibrations cause hydrodynamic sound pressure

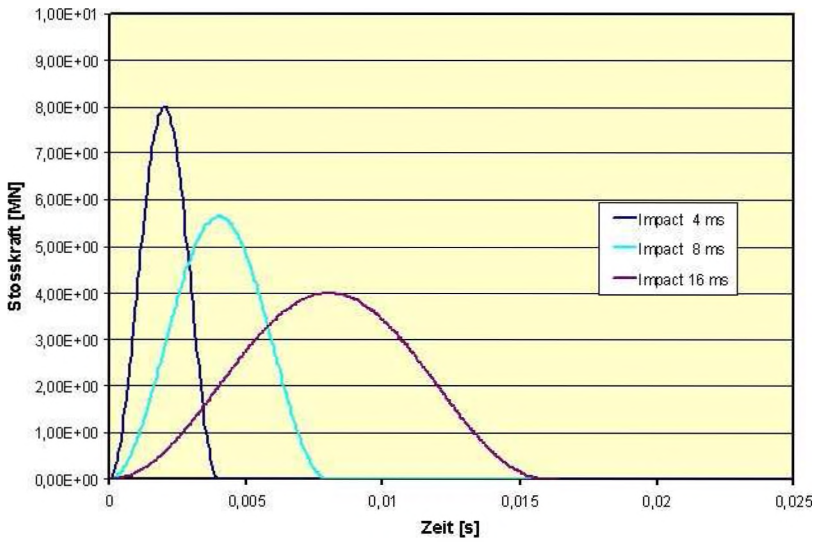

Figure 5: Impact forces of different impulse contact times with the same amount of pile driving energy

Under certain limitations, the penetration of a driven pile only depends on the amount of impact energy of one stroke and not on the impact force. The results of pile driving with different impact forces but the same energy (fig. 5) are nearly the same.

In practice, the experimental full-scale offshore application of a "soft" layer between pulse hammer and pile during pile driving of the FINO 2 monopile in the Baltic Sea leads to an extension of the pulse duration from 5.5 ms to about 11 ms after fig. 6 and a reduction of the impact force.

Doubling the impact duration but using the same amount of impact energy within all measured results leads to possible reductions (fig. 7) of 13 dB to the peak sound pressure level L_{peak} as well as a reduction of 10 dB to the single event sound level L_E or SEL.

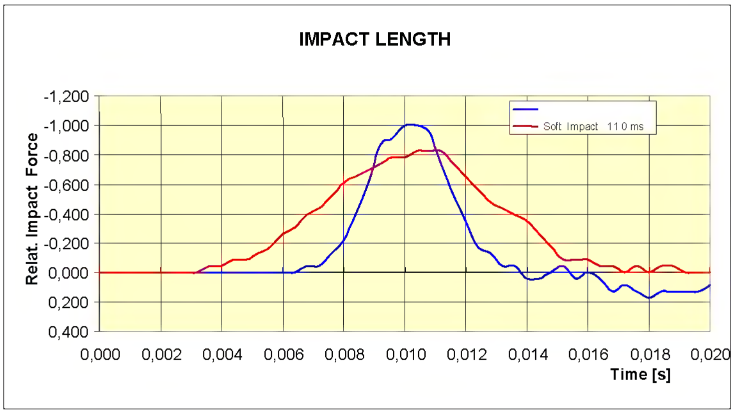

Figure 6: Measured impact forces with hard and soft layers.

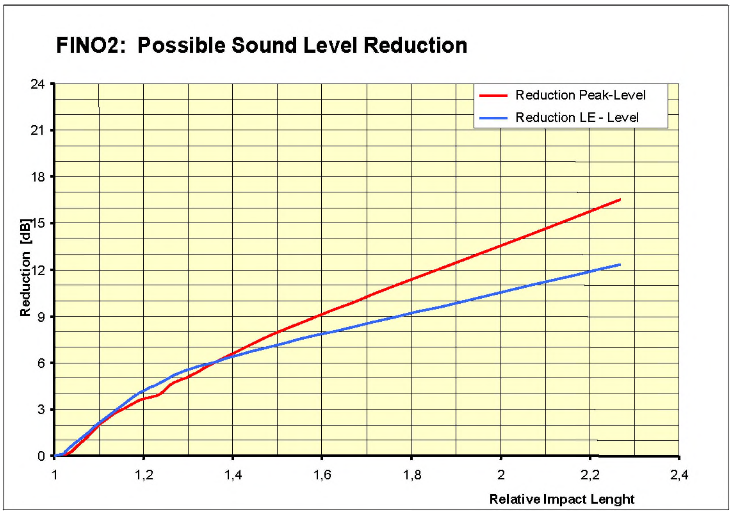

Figure 7: Possible sound levels resulting from prolonging impact duration

The reduction of energy based sound levels such as the single event sound level and the third octave analysis is smaller than the reduction of the peak sound pressure level, as the impact energy remains the same.

Using vibrators for small piles

Another primary noise reduction method is the use of unbalanced vibrators for pile driving of small piles into an appropriate seabed instead of using a hydraulic hammer. An impact hammer induces underwater noise in a large frequency range of up to several thousands Hz (fig. 8).

Unbalanced vibrators operate with continuous vibrations of frequencies between f ≅ 20 ÷ 40 Hz. Most of the noise is radiated within this frequency range (fig. 9), to which mammals do not react very sensitively.

The noise reduction during pile driving when using vibrators is about 15 – 20 dB. But pile driving using vibrators is limited to certain soils and small piles.

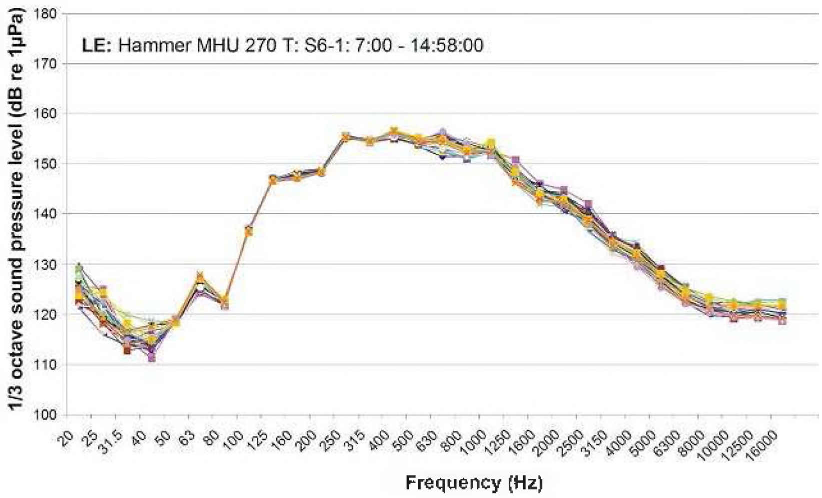

Figure 8: 1/3 octave noise spectrum of an impact hammer

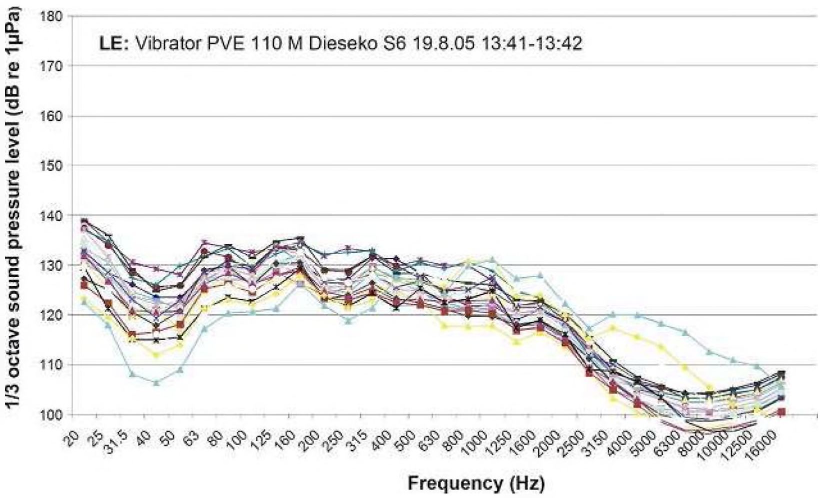

Figure 9: 1/3 octave noise spectrum of a vibrator

Air bubble curtain

In the secondary, passive noise reducing methods the transmission path of the acoustic noise immission into the water is modified.

A curtain of small air bubbles in the water around the pile reduces the underwater sound propagation.

Water, filled with air bubbles, is compressed and acts as a discontinuous absorbing medium. Noise transmission is reduced by the scattering, multiple reflection of travelling acoustic waves and mainly the by the dissipation of vibrating air bubbles.

The single vibrating bubble represents a ball emitter, whose dissipation factor directly depends on the frequency and the bubble diameter. The characteristic absorption curve of a bubble curtain likewise depends (fig. 10) on the concentration of the bubbles in the water.

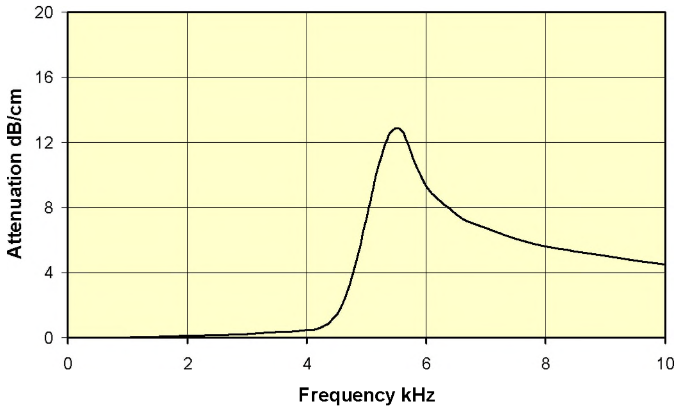

Figure 10: Characteristic curve of attenuation of an air bubble curtain.

In the example shown in fig. 10, the air concentration is about $5*10^{-5}$ and the diameters of the air bubbles are between 0.6 and 0.7 mm. The attenuation effect of the bubble curtain is to be seen above the resonance frequency of about 5 kHz and shows its maximum near the resonance frequency of the air bubbles.

In practical applications noise reductions between 5 and 20 dB are realized. But according to the strong currents in the Sea, especially in the North Sea with a flow velocity of 2m/s, it is an unsolved problem to keep the air bubble curtain concentrated around the driven pile in water depths up to about 30 – 40 m.

Coated tube as sound barrier

A noise barrier based on the mismatching of acoustical impedances between the material of the barrier and the water represents a further secondary, passive noise reduction method by modifying the transmission path.

In the Baltic Sea, a foam coated tube of 2.2 m diameter (fig. 11) fastened onto a pile. The steel pile and the coated foam material layer of 5 mm represent discontinuities on the transmission path of the traveling sound waves. The attenuation of sound waves, passing through this barrier of different materials strongly depends on the materials different results of sound velocity and density. Each transmission of waves from one material to another and into the water is accompanied by reflections and energy lost with the effect of reducing the acoustic noise immission into the water.

Figure 11: Coated tube over a pile in the Baltic Sea.

A steel pile alone or one with a rubber layer, show shallow noise reductions (12). With a foam coated steel pile, noise reductions of 5 to 25 dB (depending on frequency) are measured (fig. 12).

Much larger values were recently achieved on a scaled sound barrier model made of a foam layer between polyester tubes.

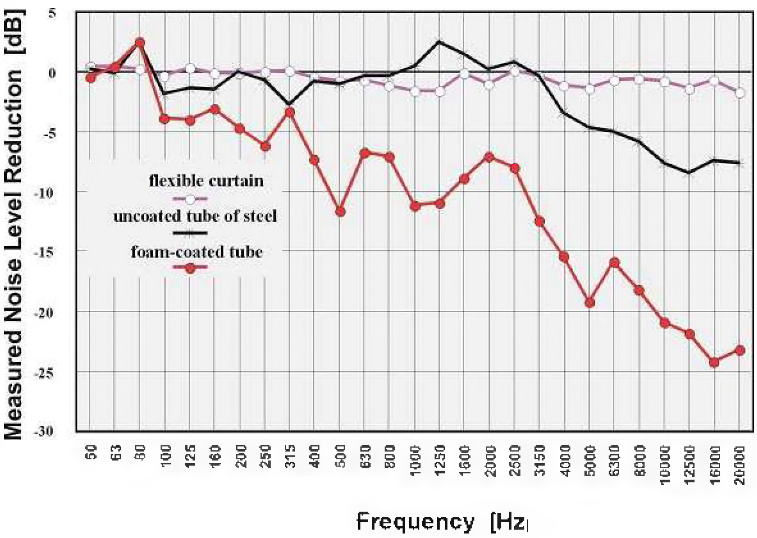

Figure 12: Frequency dependent noise reduction.

Conclusions

The high hydro noise levels during pile driving of offshore wind converters are potentially harmful to marine mammals like harbor porpoises.

Practical noise reducing methods are derived from measured results and numerical simulations. The suggested active and passive methods achieve noise reductions up to between 10 and 20 dB alone, and more, when used in combination with other methods.

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Effects of sound immissions on marine mammals

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Acoustic studies conducted as part of research on effects of offshore wind turbines are focussed on harbour seals (*Phoca vitulina*) and harbour porpoises (*Phocoena phocoena*). Grey seals (*Halichoerus grypus*), the third marine mammal species inhabiting German waters, could not yet be included in these studies even though significant data on their acoustic sensitivity is lacking and hence an assessment of effects of offshore wind turbines on them will be impossible.

What significance does sound have for marine mammals? In general these animals use sound underwater for communication, localisation and characterisation of prey, orientation and predator avoidance. However, harbour seals and harbour porpoises show clear differences regarding the extent to which they use sound signals and of what significance they are to them.

Effects of sound on marine mammals can roughly be grouped into four spatial categories in relation to the received sound pressure level. The range of audibility of a sound for a marine mammal reaches out the farthest, while at closer range behavioural reactions of the animals can be expected. With decreasing distance to a sound source, the animal's perception of other acoustic signals can be masked and at close range those immissions can reach levels, which might cause a temporary or even a permanent impairment or damage of the animals. Moreover, the perception of sound is likely to cause an increasing amount of stress in the animals with increasing sound pressure levels.

A number of different parameters has to be taken into account for the assessment of effects of sound on marine mammals. These include the ensonified area in relation to the size of the animals' habitat, the alteration of behaviours of the animals as well as the question whether the animals will habituate to the sound immissions or rather be sensitised. Furthermore, the auditory impairment due to a temporary or permanent threshold shift and chronic effects due to long-term exposure to sound are of importance.

For harbour seals the range of perception for sound emitted during the construction of offshore wind turbines extends to far beyond 100 km based on data on their hearing sensitivity on the one hand and acoustic characteristics of the ramming sounds on the other hand. For example, sound pressure levels measured during ramming activities at a distance of 33 km, were approximately 50 dB above the hearing threshold of harbour seals in a frequency band below 4 kHz. This frequency range is insofar of special importance, as the animals' communication signals lie within the same range.

The operational noise of offshore wind turbines of 1.5–2 MW power output will also be detectable for harbour seals in the same frequency range over distances of 5 to 10 km. The given detection ranges can vary due to individual variability in the hearing sensitivity and depending on the emitted sound, which will vary in relation to size and type of the wind turbines, sediment type and bottom topography.

In general the behaviour of marine mammals is highly variable. Harbour porpoises as well as seals show context specific, strongly differing thresholds for the elicitation of reactions. Observations made so far have for example shown that harbour porpoises reacted during the construction of the offshore wind turbines at Horns Rev over distances of more than 14 km.

Those animals were observed showing clear avoidance behaviour by swimming in a direction away from the sound source. A similar behaviour was observed during piling activities in the harbour of Kerteminde, Denmark in harbour porpoises, which are held in the same area. Those animals showed an increased swim speed, “porpoising” (leaping out of the water) and also “logging” (resting behaviour at the surface). As areas of reduced sound intensity can occur near the surface the latter behaviour might be a potential way of using such a sound shadow zone. Those behaviours were completely eliminated by using an air-bubble curtain, which was installed between the ramming site and the animals’ enclosure. The animals returned to their normal swim- and dive behaviour. Acoustic measurements of the ramming sound in front and behind the air-bubble curtain revealed an effective sound reduction of 18 dB behind the bubble curtain over a frequency range from 500 Hz to 22.4 kHz. THOMPSON (2000) documented comparable reactions to impulsive sounds in harbour seals within a controlled exposure experiment after exposing the animals to airgun impulses. Besides a bradycardia the animals showed clear avoidance reactions, prolonged surfacing periods, short and shallow dives and no more feeding behaviour. However, the animals returned to their normal behavioural pattern and returned into the previously used area after the end of the experiment.

The potential acoustical masking effect of the operational noise of the offshore wind turbines was tested in a study on a harbour porpoise at the ‘Dolfinarium Harderwijk’, The Netherlands. After measuring the animal’s hearing threshold in a quiet environment these hearing tests were repeated in the presence of simulated operational noise of a 2 MW offshore wind turbine. The results showed that the perception capabilities were not impaired at a received level of the operational noise at 115 db_{pp} re 1µPa in 1 m while at a received level of 128 db_{pp} re 1µPa in 1 m their hearing was masked within a frequency range up to 2 kHz. Based on these results it can be assumed that the operational noise of wind turbines (up to 2 MW) will only lead to masking in harbour porpoises at close distances to the turbines (up to 20 m).

Up to now no data are available on the auditory tolerance limits of harbour porpoises and harbour seals for impulsive sounds as will be emitted during the construction of the foundations of wind turbines. The noise exposure criteria, which are currently being discussed in the U.S.A. are based on data from studies on bottlenose dolphins and belugas. Thus, they are reflecting the hearing sensitivity of species, which have their highest sensitivity in a different frequency range than harbour porpoises or harbour seals. Based on the available data a combined criterion of a maximum sound pressure level of 224 dB_{pp} re 1µPa in 1 m and maximum sound energy of 183 dB re $1µPa^2•s$ for impulsive sounds and 195 dB re $1µPa^2•s$ for non-impulsive sounds is discussed. A study is currently being conducted within the scope of the project MINOS+ to measure the auditory tolerance limit of harbour porpoises and harbour seals. Based on the results from this study it should be possible to deduct noise exposure criteria for harbour porpoises and harbour seals and to define risk areas during the construction of offshore wind turbines.

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Impacts of offshore wind energy turbines on marine bottom fauna

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Abstract

The foundations of offshore wind energy farms will cause alterations to the natural marine habitat of the North and Baltic Seas. The seabed in the proposed areas for offshore wind farms is mainly characterised by soft sediments ranging from medium sands to silt. The underwater structures themselves not only provide empty space for the settlement of hard bottom epifauna, which do not naturally occur in these areas, but they also alter the surrounding natural habitat. In the absence of actual wind farms in German waters, the research platform FINO 1 was used in the project BeoFINO to study biologic processes around the underwater structure leading to alterations of the natural bottom fauna.

Shortly after installation, the surface was colonised by an epifauna consisting of few species, but reaching a high biomass. Mytilus edulis *dominated in the upper depth zone, while lower reaches were dominated by the Amphipod* Jassa *spp. and Anthozoans (mainly* Metridium senile*). Changed current conditions around the structure lead to erosion and altered sediment composition with thick layers of empty shells on the surface. Natural soft bottom fauna is strongly reduced in the vicinity of the platform, while predators and scavengers profit from the additional food source provided by material falling from the platform. The export of lighter material like faeces is predicted to spread over larger areas. Dense aggregations of pelagic fish were observed around the platform, while some demersal species also live in niches of the structure. All results are combined in mathematical models in order to compare different locations and to calculate scenarios for wind farm effects in various habitats.*

Benthological processes in the vicinity of artificial underwater structures

The bottom fauna of the ocean, also called benthos, is relatively strange to most human beings because it leads a mostly hidden existence. Only the commercially used species of fish and crabs are commonly appreciated by humans. Beyond these, a fauna rich in biodiversity lives on the bottom of the sea, which also has a special function in the marine food web. It is not only the food basis for fish, but also directly and indirectly for sea birds and marine mammals.

Figure 1: Surface of a typical sand bottom in the German Bight with starfish, sand mason worms and hermit crabs (© Suck, AWI)

Soft bottoms with surface sediments of coarse sands to silt mainly characterise the seabed in the proposed areas of offshore wind farms in the German EEZ of the North and Baltic Seas. At first sight, these bottoms do not seem to be very lively. Only a few fish, crabs, starfish and worm tubes can be seen on the surface (fig. 1). The main part of the fauna lives hidden in the ground. This bottom fauna with organisms larger than 1 mm is called macrozoobenthos. Hundreds of species and up to ten thousands of organisms can be found under every square meter of seabed.

The construction of underwater structures of offshore wind turbines introduces large artificial hard substrates into these habitats, providing space for epifaunal organisms and changing local currents, which cause scores and influence the sediments.

Within a short time after the installation of such artificial structures on the sea bottom, a depression develops through the erosion of surface sediments caused by the changed currents around the structure. A so called scour can reach a depth of several meters and an extension of tens of meters depending on the flow speed, the dimension and form of the structure, and the type of sediments. Mainly fine sediments are carried away, deeper layers of sediments are exposed whereas empty mussel shells are washed out and collect on the surface (fig. 2). Depending on the current conditions, an accumulation of fine sediments and organic material can occur in such scours, leading to massive effects on the oxygen supply in and above the seabed. In combination with thereby triggered biological processes, the habitat of the soft bottom fauna will be permanently altered.

Figure 2: Seabed directly at the platform, covered with coarse shells, star fish and edible crabs (© AWI)

An epibenthic fauna quickly colonises the artificial hard substrate, reaching a quite high biomass in a short time. Excrements of this epibenthic fauna, but also whole plaques or individual organisms sink to the seabed and become food for scavengers and predators. Such structures also seem attractive for some fish species, searching for protection and food. The accumulation of these fishes combined with the invertebrate predators around the platform cause in turn an increased feeding pressure on the surrounding soft bottom fauna.

So far it has not been possible to concretely estimate to which spatial extent these processes will happen at the planned offshore wind turbines and in which dimension this will change the diversity and the food web relations. These aspects provided impetus for the investigations of the research projects BeoFINO and BeoFINO II, funded by the Federal Ministry for the Environment.

BeoFINO (II)

Within the framework of both research projects BeoFINO (BMU-FKz. 327526 11.2001 – 12.2004) and the currently running BeoFINO II (BMU-FKz. 329974A 01.2005 –12.2007), many investigations have been carried out at the research platform FINO 1 (www.fino-offshore.de). Possible biological effects of offshore wind turbines were assessed prior to their actual construction, including investigations not feasible in future actual wind farms.

Topics of the investigation have been the epifouling fauna on the under water structure, its species composition and biomass, the chronology of the settlement and succession, as well as the depth zonation of the fauna. Attention has also been focused on the alteration of sediments and of the bottom fauna surrounding FINO 1. The observed aggregation of free swimming (pelagic) fish and the colonisation of bottom dwelling (demersal) species on and around the platform have not been quantifiable yet, and will be assessed during the current observations by means of direct counts and echo-acoustical methods. The results of all investigations are summarised in simulations with computer models to show changes in the food web and to estimate scenarios of the cumulative effects of numerous turbines.

For this purpose, a crane with a grab sampler was installed below the helicopter platform. Seabed samples can be gathered with this device in an area directly surrounding the platform of up to 15 m distance, making it is thus possible to analyse the sediments and the bottom fauna. An additional pile has been installed on the north-facing pile, guiding a camera that can be moved until just above the sea bottom. This camera is remote-controlled from the institute via the internet, and allows the observation and photographic documentation of underwater structure colonisation with a high temporal and spatial resolution.

Figure 3: Sampling of the underwater structure by divers and of the surroundings from the ship (© AWI).

Several expeditions per year were carried out to explore the outer surroundings of the platform from shipboard, while divers gathered samples of the epifouling fauna. The divers also made videos and photographs of the fauna. In the future, aggregation of schools of fish will also be investigated by a scientific horizontal echo sounder.

Colonisation of the underwater structure

The underwater construction of FINO 1 represents an artificial hard substrate that did not remain empty for a long time. It was soon covered by various species that normally do not occur in the natural habitat of soft bottom. Within a few weeks after the construction of the platform, hydrozoans covered the complete surface of the underwater construction. In the months to follow, this relatively thin fouling in the beginning stage was displaced by a composition of sea mats (mainly *Electra pilosa*), sea anemones (*Metridium senile*) and amphipods (mainly the Genus *Jassa*).

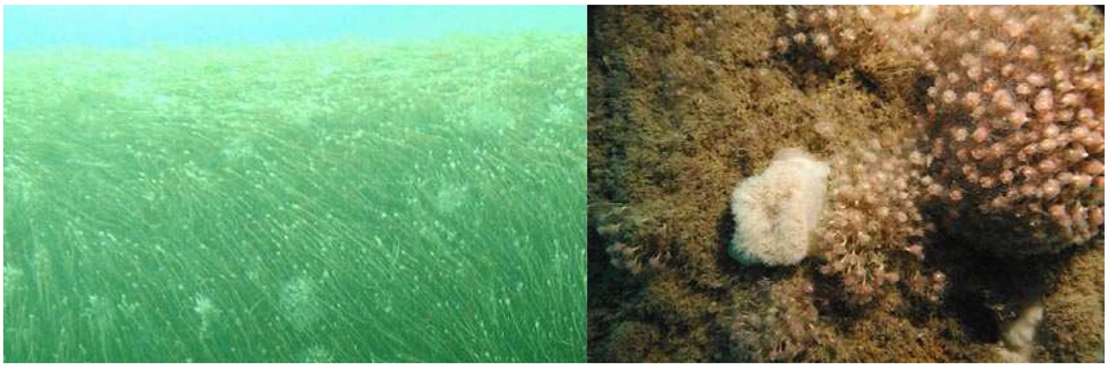

Figure 4: Colonisation of the underwater surface of FINO 1: Initial cover of hydrozoans (left) and early association of amphipod constructions, sea anemones and hydrozoans (right) (© AWI).

The constructions of these amphipods of the genus *Jassa* almost covered the whole underwater space of the platform until spring 2004. In summer increased hydrozoans occurred again (mainly *Ectopleura larynx*) and especially the upper areas up to 5 m water depth were intensely colonised by mussels (*Mytilus edulis*).

Figure 5: Colonisation of FINO 1: Mussels in the higher sections (left, 3 m), combined with star fish and amphipod growth (centre, 5 m) and near the bottom with sea anemones, amphipod growth and star fish (right, 26 m) (© AWI).

Since then, mussels cover the whole surface in shallow areas and reached a mat of 15 – 20 cm thickness within one year. With increasing depth, the dominance of mussels decreases and other species like star fish (*Asterias rubens*), amphipods (*Jassa* spp.) and sea anemones (*M. senile*) become more frequent. Mussels occur only sporadically and amphipods dominate the community in depths below 6 – 10 m. The last three meters above the seabed are less densely colonised probably because the higher sediment transportations in the water impair the living conditions for many species.

Already after one year, the colonisation reached a biomass of 2 – 4 kg/m^2, which sums up to 3.6 t on the whole surface of the platform. The colonisation of the mussels in the upper three meters contributed to a sum of around 60 kg/m^2 in the following year. The growth in deeper areas was clearly smaller, and from around 15 meters nearly the same biomass was observed as in the year before. Thus the blue mussel constitutes almost half of the whole biomass that increased up to 7 t within two years after the construction of the platform. In the third year the biomass slightly decreased and reached only 5 t. It cannot yet be conclusively determined if this is the development of a medium term stable level or just an inter-annual fluctuation. However, the currently observed extension of the settlement of mussels in higher water depths lets a further significant increase of biomass seem possible.

This dense cover is dominated by just a few species. Next to the species already mentioned, only few species occur in appreciable numbers. In larger depths sea anemones (*Sagartiogeton undatus*) and nudibranchs (*Polycera quadrilineata*, *Coryphella* spp., *Facelina* spp.) have been observed within increasing time. Other species like polychaeta and crabs were only found sporadically. Despite the high biomass, the diversity in the epifouling fauna at present is clearly smaller than that of natural hard bottom habitats like e.g. Helgoland.

Facing the observed proceeding changes of the epifouling fauna, it can be conceived that the equilibrium has not been reached yet, and that a medium term stable situation will only be reached after several years.

Changes of the surrounding soft bottom fauna

The colonisation of the hard substrate was not the only alteration of the marine fauna. Clear changes of the bottom fauna were also observed in the surroundings of the platform. Characteristic species such as the heart urchin (*Echinocardium cordatum*), the bivalve *Tellina fabula* or the polychaeta *Chaetozone setosa* were very rare in the area that could be sampled from the platform up to 15m. The latter were no longer present in the direct vicinity, whereas in the natural fauna these are a major component of the stock, as can be seen in the reference area (200-400m) (fig. 6).

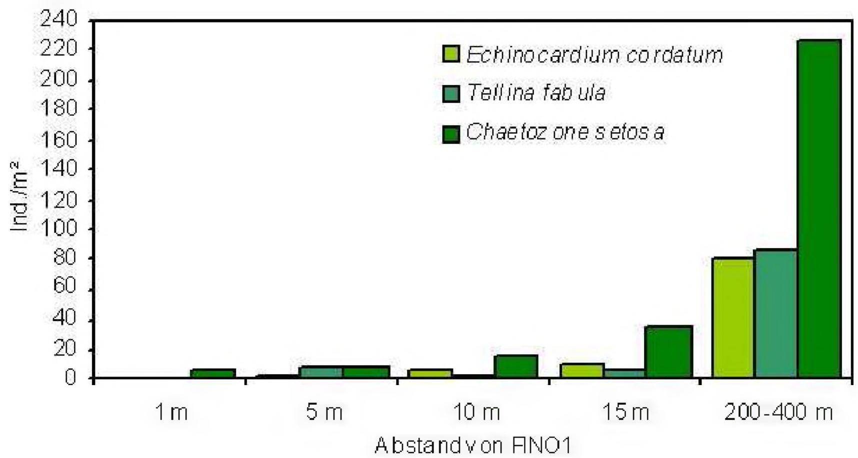

Figure 6: Densities of typical soft bottom species around FINO 1 (© AWI).

There was, however, a pronounced increase of predators and scavengers like e.g. hermit crabs (*Eupagurus bernhardus*), swimming crabs (*Liocarcinus holsatus*) and the polychaete *Eunereis longissima*. Star fish (*A. rubens*) and big edible crabs (*Cancer pagurus*) were also observed very frequently. Even if these species occur in the natural soft bottom habitat, they do not reach the densities they achieve at the platform (fig. 7).

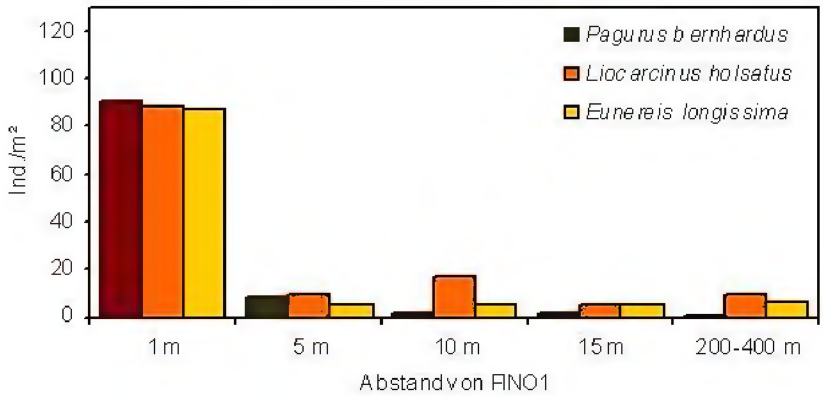

Figure 7: Densities of predatory species around FINO 1 (© AWI).

These alterations of the fauna go along with the changes of the sediments around the platform. The changed conditions of the current produced scours of depths around 1.5 m (personal observation). A layer of empty shells of several dm has accumulated at the surface, which were washed out of the sediment. The composition of sediments is one of the decisive factors for the composition of the marine soft bottom fauna. For a lot of soft bottom species the changed sediment caused by the scouring does not allow to live there.

Fish

Schools of fish looking for protection and/or for food can be observed around large underwater structures. Aggregations of fish have also frequently been observed around FINO 1 with the remote-controlled camera, in video recordings and by divers. In the shallower areas these were mainly horse mackerels (*Trachurus trachurus*, fig. 8,left).

Figure 8: Horse mackerel (*T. trachurus*) around the platform (left) and sea scorpion (*Myoxocephalus scorpius*) on the platform (right) (© AWI).

Bibs (*Trisopterus luscus*) and other gadoids (Gadidae) have been sporadically observed in the areas at the bottom. Sometimes Bull-rout (*Myoxocephalus scorpius*, figure 8, right) or butterfish (*Pholis gunnellus*) can be found in niches and corners of the underwater structure.

Whether these are only short-time aggregations, or if the animals benefit from this habitat, and thus impacts on their stocks could be deduced, is yet unknown and part of future investigations with a horizontal echo sounder and through in-situ counts.

Development of models

To be able to analyse the functional changes in the marine faunal community, the investigated empirical data are integrated into mathematical models in order to finally calculate generalised scenarios for various habitats. Cumulative effects of numerous turbines shall be eventually assessed by these means.

A persistent rain of additional organic material trickles permanently down from the epifouling fauna onto the surrounding seabed. This consists on the one hand of excrements from the animals and on the other hand of dead and living organisms, parts of their constructions or whole lumps of organisms that occasionally fall down. This material represents not only an additional source of food. Its quality is in principle different to the common food of the bottom fauna. The excrements, as already digested material, contain fewer nutrients and can be used by only few organisms. However, especially predators and scavengers benefit from larger sinking organisms. Thereby some groups of organisms are supported selectively, while others are disadvantaged. This can cause alterations of the community structure of the soft bottom fauna.

Based on currents measured at FINO 1 (BSH), a mathematical model was developed in order to simulate the distribution of the material around the platform depending on the size of the particles and of the sinking speed at the prevailing current conditions (fig. 9).

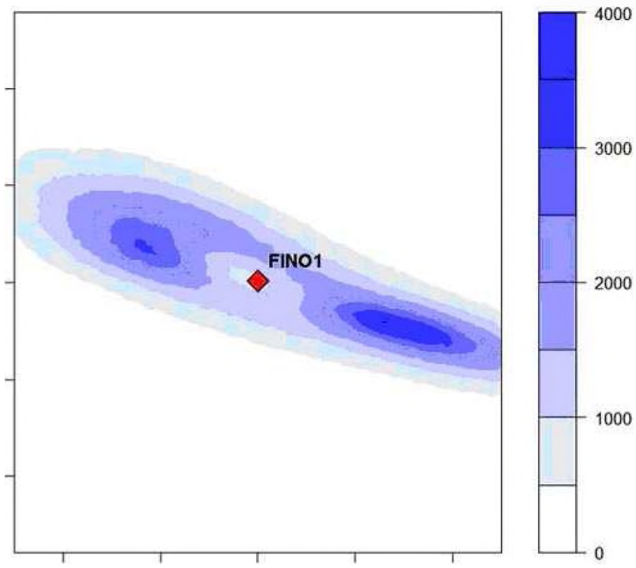

Figure 9: Simulated distribution of particles around the platform FINO 1. Scaling and quantification at present only relative values. Absolute values are currently assessed (© Potthoff, AWI).

Sensitivity analyses of the involved parameters are used to characterise essential parameters and identify knowledge gaps, which must be tackled in further investigations. In order to be able to quantify the spatial dimension and the distribution of the material, the input parameters such as the type and mass of the material, sinking speeds and temporal distributions have to be appraised in more detail before realistic scenarios can be simulated.

On the basis of this model of distribution, different scenarios of various habitats are simulated with a trophic structure-model. These are the basis for a spacious simulation of cumulative effects caused by large offshore wind farms, and finally thousands of turbines in the German EEZ that are needed for the achievement of the defined energy political aims.

Alterations of the marine bottom fauna caused by offshore wind energy turbines

Alterations that are expected from the construction of offshore wind energy turbines in a soft bottom habitat of the North Sea can be assessed on the basis of the investigations made at the research platform FINO 1. As the underwater constructions of offshore wind turbines will have similar structures as the platform, the development of the fauna will presumably follow a similar pattern as observed at FINO 1. Differences may be expected due to different materials and/or different sizes of the underwater surfaces e.g. at monopiles or tripods. The latter can be considered in the mathematical models by adjustment of parameters. The colonisation of different materials is part of further studies.

In all cases, a colonisation of species alien to the natural habitat is expected, which will reach an equilibrium only after several years. A considerable export of organic material that can be distributed over larger areas has to be assumed because of the high biomass of the epifouling fauna. Significant changes of the bottom fauna around the foundation structures are faced, as the typical soft bottom fauna decreases while predators and scavengers benefit. While it is assumed that the direct impacts of the structure through scores and changes of the sediments have a limited radius of around 50 – 100 m, the area influenced by biomass export may extend up to hundreds of meters if current conditions are similar to those at FINO 1.

Thus, altogether a significant alteration of the habitat has to be expected. Local changes around hard substrate structures can also be found at shipwrecks that are widely spread in the German Bight. In comparison to wrecks, which mostly jut out a few meters above the sediment, the foundations of wind energy turbines extend over the whole water column, which causes totally different effects. Especially in the North Sea, a dense settlement of blue mussels occurs only in the higher sections, but contributes the bigger part of the total epifouling biomass. Therefore they are responsible for the bigger part of the food conversion, filtering plankton and producing excrements that trickle to the seabed. The deeper areas down to approx. 5 m above the bottom are also thickly covered and show a clear seasonal rhythm of accumulation and reduction of biomass. The deeper meters near the bottom of the sea are thinly covered and play a relatively small part in food conversion. The expected dimension of habitat changes caused by the artificial substrate is therefore not proportional to the pure number and extent of the artificial surfaces, but rises disproportionately with increasing proximity to the water surface. So it can be assumed that offshore wind farms have a significantly different influence than shipwrecks or even natural hard substrates.

The changes of the sea bottom fauna are dependent on different factors such as species composition, sediment, currents and the local primary production and thus are only to a limited extend transferable to other habitats. In the Baltic Sea, where currents, salinities and species compositions are significantly different, there is an entirely different initial situation that may result in completely different results. These differences are analysed in collaboration with the Baltic Sea Research Institute Warnemünde (IOW), who carry out comparable studies in the Baltic Sea. By adaptation of the mathematical simulations and integration of the relevant initial parameters, a model is developed that allows a comparison of regional processes and the construction of different scenarios for various habitats.

Indirect effects can hardly be forecasted because the food web and the ecological interactions in a marine ecosystem are very complex. Especially here exists a significant need for research before forecasts about the regional impacts of numerous offshore wind energy turbines can be made. Secondary uses must also be considered in this context. Issues such as aquaculture and the open question of whether and how fishing in wind farms will be allowed must be examined. With the exclusion of especially sensitive areas and by optimising the underwater structures and the construction works of the foundations and cable laying, an as much as possible environmentally compatible use of wind energy can be achieved also in offshore areas.

Detecting hidden objects aloft: Technical developments for the quantification of bird migration offshore and bird collisions

J. Kube, J. Bellebaum, A. Schulz, H. Wendeln

The establishment of mitigation measures for the collision risk of flying birds at offshore wind farms requires at least to two types of information, which can be obtained only by extensive field observations: (1) a quantification of bird migration in relation to weather and (2) a quantification of collisions in relation to weather. Both data are difficult to obtain, because: long-term observations by man cannot be carried offshore, most birds migrate out of visibility (altitude, daylight), and most collisions will occur at night, when they can not be observed by eye.

The registration of bird collisions at offshore structures was investigated twice in recent years (NERI at Nysted offshore wind farm, IfV at FINO I). Both investigations applied infrared cameras with remote tracking device and data storage. Both investigations revealed certain disadvantages. (1) The system cannot track during rainy weather. (2) The resolution of infrared cameras is not sufficient to track passerines in the vicinity of the rotor of a large wind turbine, and (3) those systems are too expensive, to obtain a data amount sufficient for a statistical approach.

The Institute of Applied Ecology, Broderstorf, therefore, develops an alternative video system, based on high-resolution CCD daylight cameras in combination with infra-red headlights. The system is currently under development. First tests on top of a turbine in Rostock harbour revealed the requirement of certain software tools to compensate for vibrations of the engine pod and the rotation of the blades.

Our institute also develops a mobile fixed beam radar for the quantification of nocturnal bird migration. Large scale military or weather radar will not be sufficient for the establishment of a quantitative bird migration model for forecasting of nights with a high risk of mass collisions at offshore wind farms, since they fail to measure birds at low altitudes (< 100 m). Thus, small sized radars are required to fill this gap. The fixed beam radar system, based on technical developments of the Swiss ornithological Institute Sempach and Software Büro Steuri GmbH (Switzerland), allows for a quantitative approach based on a qualitative analysis of wing beat frequency and wing beat pattern of the tracked flying objects (birds, bats, insects).

Methods for investigating bird migration

Dipl.-Geogr. Reinhold Hill & Dr. Ommo Hüppop
Translation: Alexandra Toland, Leena Morkel – TU Berlin

Questions on bird migration with regard to offshore wind farms

The collection of data on bird migration with the most automated and high-tech aids available serves to answer open questions about migration intensity, altitudinal distribution and species spectrum, with regard to daily and seasonal patterns, weather and other environmental factors on the open sea. In connection with the planned offshore wind farms in the German Bight (HÜPPOP et al. 2004, HÜPPOP et al. 2006a), questions arise regarding the influence of weather on birds and the reaction of migratory birds to offshore wind energy turbines: under which conditions do birds fly at „dangerous altitudes“, when do they dodge obstructions, when do they collide and are we able to predict such behaviours?

The following methods have been used and are being further developed for the documentation and data collection of bird migration.

Visual survey

From a technological perspective, identification by visual observation is one of the simplest methods, which has been successfully used for many decades and has also recently been substantially standardized (e.g. DROST in 1928, and more recently in HÜPPOP & DIEN 1984, GATTER 2000 and DIERSCHKE et al., 2005; see fig. 1). This method requires a very good knowledge of bird species and birdcall identification as well as good visibility conditions. During the day migration intensity, altitude and direction may be determined or at least estimated by visual observation, whereby only a certain range of a few hundred meters above land or sea can be covered. With the exception of just a few species, a separation between foraging flights and migratory journeys is possible to determine based on the different behaviours of birds. Detailed information about this method of observation is available in HÜPPOP et al. (2004) and DIERSCHKE et al. (2005). Results from the BeoFINO project are presented in HÜPPOP et al. (2005).

Figure 1: Standardized observation of migrants on the island of Helgoland

Video camera

By good visibility conditions, video cameras may be employed for the automated documentation of bird activities during the day. As with thermal imaging cameras (see below), the choice of focal length is to be seen as a compromise between magnification and angle of view: if the focal length of the lens is in the range of a short telephotographic lens, the field of view is relatively large, but only large birds will be seen in the recorded images. Distant birds may not to be recognizable with such a small resolution however. If one adjusts the camera lens to a large focal length with a correspondingly low shutter speed, birds at close proximity can be recorded as well as birds at some hundred meters distance away. Because of the small field of view only a few birds are captured however. Software for the automated capture of images at peak storage technique / mode is used on the FINO 1 (fig. 2). In this way the incoming video data stream from the camera, converted by a video capture card in the PC, is added up over a time period of five minutes by the computer. For each individual pixel, the brightest and/or darkest pixel (peak) is stored in each case in the form of two separate pictures over the course of the entire time period. Thus „flight tracks“ develop from the birds’ motions, which also contain information about approximate directions and flock sizes. Even distant birds or birds flying directly over white crest waves or breaking waves may be registered. Fog and drizzly rain significantly reduce the range of vision of the video cameras. Species identification is nearly always problematic with PAL resolution (768 x 576 pixels). Seemingly disoriented birds have been recorded at night in the spotlight beams of the platform.

Figure 2: Birds recorded with the "peak storage technique" video system on the FINO 1.

Thermal imaging (infrared) camera

Depending upon the model, thermal imaging cameras are suitable for the calculation of bird migration under clear sky conditions up to approximately 3 km in height (e.g. LIECHTI et al. 1995). Individual members of flocks are partially recognisable as well as species groups at close range, which makes the technology predestined for strike studies. The disadvantages of this technology however, include the high cost of the equipment and the inferior ability for determining distance, as compared with radar devices. Furthermore, there is a constant compromise between angle of view and resolution and/or range with this method as well. The capturing software also renders images of a certain time period, so that birds in flight are represented by „target tracks" (peak storage technique, see below).

Due to high costs, the resolution of the thermal imaging cameras used on the FINO 1 is only 320 x 240 pixels. A clear differentiation between the surface temperature of birds, with their well insulated plumage, and that of low clouds, mist and fog has proven to be a frequent problem. Birds are more detectable before the backdrop of a cloudless sky than that of a comparatively warmer background. Depending on droplet size and density, heavy rains or dense fog can significantly degrade the image detectability of birds, as radiant heat is reflected and absorbed by water droplets. Further details about these and other methods are described in HILL & HÜPPOP, 2006. Mass accumulations of seemingly disoriented birds have been recorded time and again in the spring and autumn on the FINO 1. Attracted to the platform, the birds often hang out for hours in its direct proximity, increasing risk of collision (fig. 3).

Figure 3: Small birds in close range of the FINO 1, recorded by a thermal imaging camera at "peak storage technique".

Multi-sensor platform

In a project on behalf the German Federal Armed Forces, a compound sensory system, otherwise exclusively used for militarily operations, was tested for its suitability for bird migration observation (HÜPPOP et al. 2007). The multi-sensor platform 500 (MSP-500) makes it possible to detect objects during the day and night, to track them automatically, measure their distance from the platform and if necessary record movements on video. The device has at its command a video camera and a thermal imaging camera, each with interchangeable lenses as well as a laser rangefinder for determining distance. The thermographic camera has a resolution of up to 768 x 576 pixels. Information about date and time as well the vertical and horizontal positions of objects being tracked in relation to the MSP are faded into the video stream renderings of the thermal imaging camera, which may be used for further analyses. Calculation of distance is made with a laser rangefinder with a maximum range of 40 kilometres. The resolution accuracy for individual objects is up to five meters, but can be reduced to capture a flock of flying birds at up to 20 meters (multiple target resolution). The thermal imaging system in combination with the distance-measuring device is suitable for the exact measurement of flight paths in three-dimensional space, which makes it especially suitable for the documentation of sudden avoidance / dodging movements as well as collisions. Measurements of speed, flight altitudes (and changes), as well as information about direction and migration intensity can be made around the clock. The identification of different species with the thermographic camera is however quite limited. The disadvantages of this system also include very high procurement costs and an enormous expenditure in personnel. The maximum observation ranges of migrating birds are specified in tab. 1.

Table 1: Maximum observation ranges of the MSP-500:

	approx. range in km
Individual songbirds	> 1,5
Individual wading birds	> 3,0
Flock of ducks	> 5,5
Flock of geese	> 7,0

Horizontally and vertically rotating marine radar / marine radar with rotating parabolic antenna

Marine radars are a relatively inexpensive and mobile alternative for examining local migratory movements of birds (e.g. already WILLIAMS et al. 1981). Depending on the task at hand, the devices can be used in the „normal“ setting with a horizontally rotating fan beam antenna, but can also be used to measure altitudes (plane of rotation tilted vertically at 90°) and/or can be re-equipped with a parabolic dish antenna (COOPER et al. 1991). Horizontally operated marine radars are essential in the determination of migratory directions as based on flight patterns. With the help of vertically oriented radars, flight altitudes and intensities are easily calculated and approximate flight directions determined, whereby the detectability of a bird is dependent on its distance from the device and must therefore also be considered (HÜPPOP et al. 2004).

Nevertheless, conclusions about species spectrum and flock size are hardly possible. Heavy swells (with the use of horizontal radar) and precipitation (with both types) result in unfavourable effects. Birds flying directly over the water surface merge into swells on the radar, while birds at distances of more than about 1.5 to 2 km are no longer detectable. Covered to a large extent however are the altitudes of birds that are no longer observable with visual and acoustic registration and those which are not detectable e.g. by large scale surveillance radars because of the curvature of the earth. During the darkness of night, mobile or stationary naval radars, alongside thermal imaging cameras, are presently the only way of calculating bird migrations from just above the water’s surface to heights of more than 1.5 km. It must be considered however, that detectability depends strongly on an object’s size in addition to current atmospheric conditions, e.g. water vapour or particles. While flocks are discernable right down to individual birds in direct proximity of the radar, the radar device is not suitable for the investigation of collision risks. Available radar technology cannot carry this out because of the low resolution. For example, it is not possible to recognize whether individual birds will be „knocked out“ of a chain of flying ducks. On the other hand, radar can be a suitable method for calculating spatial horizontal and vertical avoidance movements. Marine radars use pulsed signals. The manufacturers thereby automatically combine the user-determined measuring range of their devices with pulse lengths and pulse rates. In order to increase the spatial resolution of smaller ranges, high pulse rates are thus combined with short pulse lengths. The smaller pulse volume resulting from smaller pulse length clearly reduces the detectability of small objects such as birds at greater distances. BRUDERER published fundamental technical theories on radar ornithology (BRUDERER 1997a and 1997b). Constant settings must be maintained for the comparability and quantitative collection of data. This is especially important with the vertically rotating radar, whereby a constant range of 0.75 nautical miles (1 nm = 1,852 m) is used. This setting is a compromise between high resolution and long distance measuring (over open seas). Detailed information and results of the measurements on FINO 1 are described in HÜPPOP et al. 2005, 2006a, and 2006b and HÜPPOP & HILL 2007.

Since its earliest success, a rotating antenna still seems to be the most promising device for the determination of flight direction. Methods for decreasing „sea clutter“ in the use of horizontal radars (see above) are currently being tested. The use of a self-rotating, parabolic dish antenna, slightly inclined over the horizon and featuring a circular radar signal (pencil beam) with a smaller degree of beam width is being tested in place of the former fan beam antennas with their fan-like radar waves and a vertical beam width angle of 20°.

Non-rotating marine radar

In a project on behalf the German Federal Armed Forces, a modified Furuno marine radar was employed in the study of wing beat patterns and frequencies of migrating birds for the first time (HÜPPOP et al. 2007). A parabolic dish antenna replaced the fan beam antenna and an exemplary and economical method could thus be tested for the identification of migrating birds according to species. In contrast, previous studies of wing beat frequency and the subsequent diagnoses or identification of species and/or groups of species were based predominantly on the use of military tracking radars (e.g. BRUDERER 1969, BRUDERER et al. 1995, BRUDERER 1997a, 1997b).

Groups of species can be identified by their characteristic wing beat frequencies, or rather by typical changes in the backscatter intensity of radar signals. Fluctuations in backscattering intensity result from changing radar backscattering intensities (or radar cross-sections), which occur at each stroke of a wing-beat of a bird. A further role is also played by the angle at which the bird traverses the radar beam (aspect). The pattern of wing-beats as well as the interval between active wing-beat phases, at least with songbirds, characterizes certain types of flight, which may then be assigned to different species (BRUDERER 1969, BRUDERER et al. 1972, HOUSTON 1973, FLOCK 1974, BLOCH et al. 1981, BRUDERER 1997a).

Generally speaking, the faster the flapping frequency, the smaller the body mass of the bird (BRUDERER 1969). The frequency of the wing-beat may also distinguish small birds from insects (FLOCK 1974, DRAKE et al. 2002). This possibility for distinction could particularly increase the quality of the radar data in the summer half-year within the offshore range. On the basis of these conditions, the recent testing of modified marine radars took place for the characterisation of bird migration according to species groups (fig. 4). The potential of this method for the measurement of migration intensity and altitude distribution could also be tested in order to supplement or if necessary even replace alternative radar methods (vertically rotating radar) in the future.

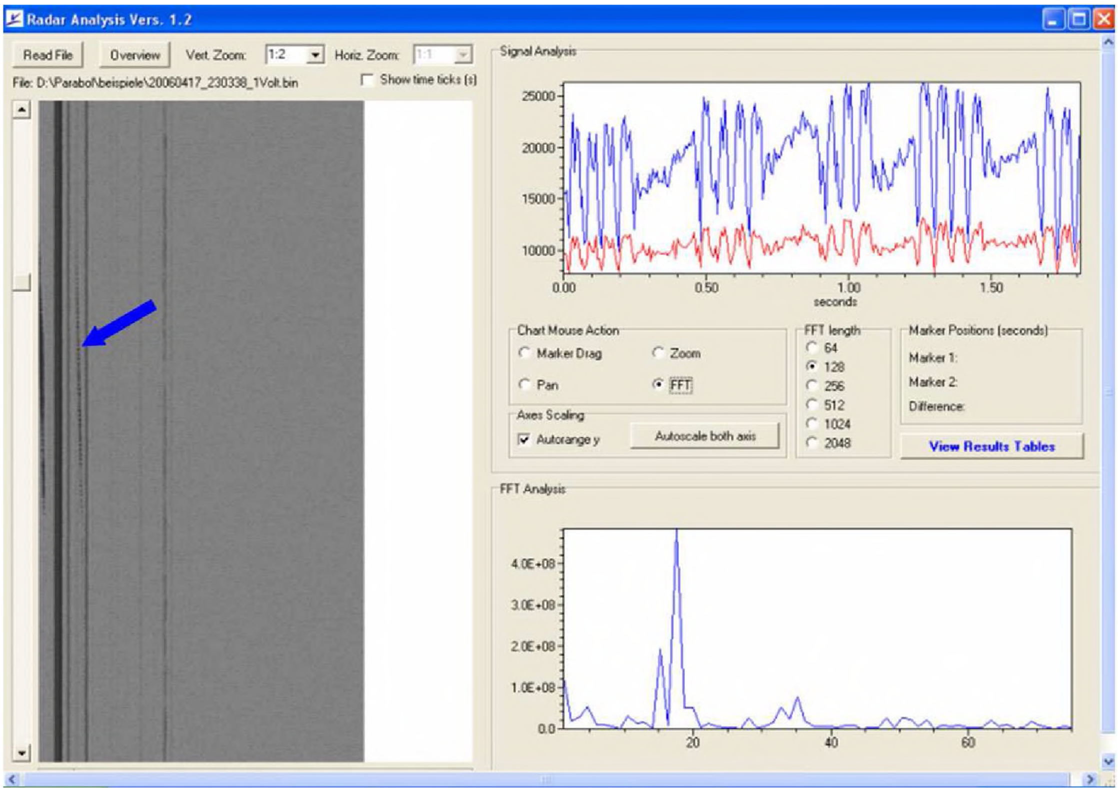

Figure 4: Wing beat pattern of a songbird, recorded by a non-rotating antenna.

Microphone and bat-detector

Acoustic detection is the technically most uncomplicated of all of our methods. It has worked satisfactorily for many decades and has been recently standardized. Recordings at sea are often degraded by strong wind noises, but may be automated with certain restrictions (see DIERSCHKE already in 1989). It is to be noted that acoustic data collection is not suitable for the sole quantification of bird migration, as some species of birds utter no calls during their migration, while others increase their call activity in fog, during poor visibility conditions or when they are attracted to light (ALERSTAM 1990). For the recording and automated recognition of birdcalls, a directional microphone with windshield and a mic muff is used. Our self-developed capturing software, AROMA (Acoustic Recording of Migrating Aves), automatically recognizes birdcalls by their characteristic sound spectrum and filters out wind and rain noises to a large extent. The call intensities of the most frequently recorded species on the FINO 1 show a very characteristic migratory pattern, which largely corresponds to studies of birds captured and ringed on the island of Helgoland (HÜPPOP & HILL 2007). Nights with substantial bird migration or also nights with masses of disoriented birds are at the same time potential multiple strike nights, whose weather-conditioned causes are not yet entirely clarified and thus still hardly predictable. Results of the measurements on FINO 1 are described in HÜPPOP et al. 2005, 2006a and 2006b.

With the operation of the bat detector on the FINO 1, migrating and hunting bats could also be detected. Detailed data are also available in HÜPPOP & HILL 2007.

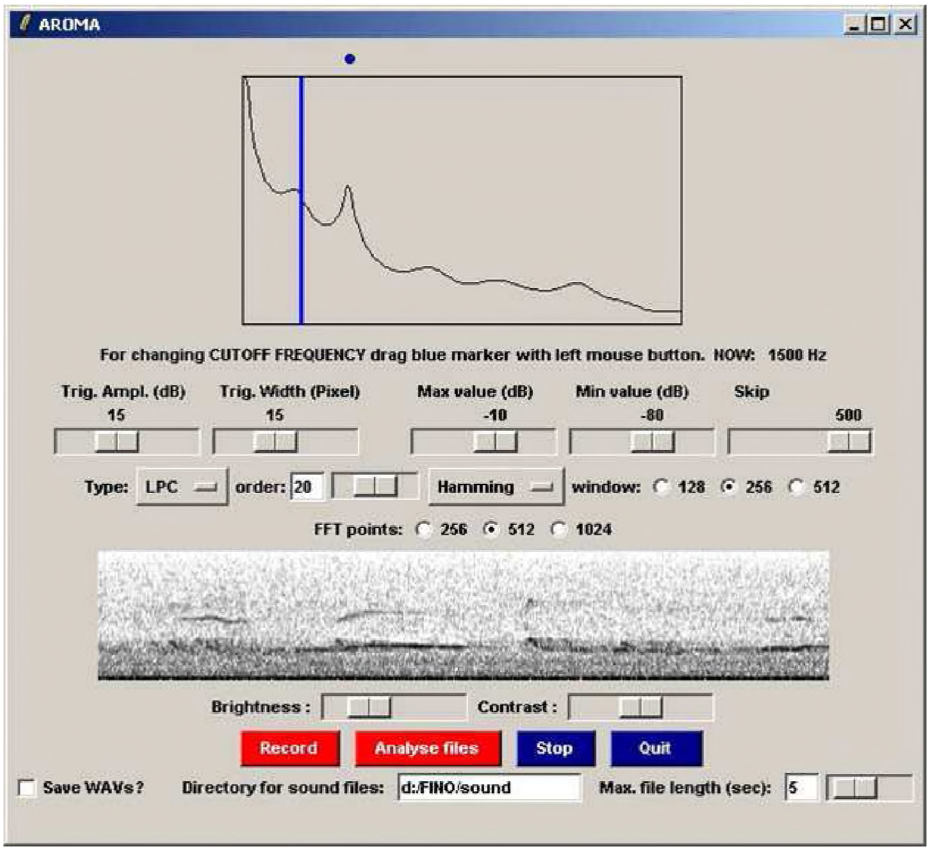

Figure 5: The data recording software AROMA filters birdcalls out of incoming audio noise from the microphone and saves these as audio data files.

Modelling and forecasting

For the successful modelling and forecasting of bird migration with regard to offshore wind energy plants, the following questions are to be prioritised:

1. Under which conditions does bird migration take place and at what intensity?

2. How many individuals and under which conditions are birds either attracted by lighting, or take actions to avoid the turbines?

3. Under which conditions do birds collide with turbines? What are the cumulative effects of many offshore wind farms?

To some extent, models have already been developed in several different projects at the Institute of Avian Research "Vogelwarte Helgoland" to answer these questions, while other models are still lacking or to be improved and represent a possible focus for future work.

Acknowledgements

We would like to thank our co-workers and colleagues from various projects for their cooperation and support. Above all we would like to thank our sponsors:

- Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, (BMU, FKZ 327526 and 0329983)
- Federal Agency for Nature Conservation (BfN)

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Offshore wind farms: Effects on the water exchange of the Baltic Sea

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Translation: Leena Morkel, Alexandra Toland – TU Berlin

Abstract

Only recently, medium intensity inflow events into the Baltic Sea have gained more awareness because of their potential to ventilate intermediate layers in the Southern Baltic Sea Basins. With the present research activities within the BMU project QuantAS-Off (Quantification of water mass transformations in the Arkona Sea – Impact of Offshore Wind Farms) a first attempt is made to obtain estimates of turbulent mixing in this area where dense bottom currents resulting from medium intensity inflow events are weakened by turbulent entrainment. With the help of cruise- and station-measurements, numerical local- and regional-scale modelling and lab modelling, scientists from the Baltic Sea Research Institute, the University of Rostock and the University of Hanover are bringing their knowledge and techniques together to obtain an estimate of additional turbulent mixing of Offshore wind Farms to dense bottom currents. This estimate is then being implemented into a high-resolution regional model running at the Baltic Sea Research Institute of Warnemünde. This numerical model simulation, which is carried out using the General Estuarine Transport Model (GETM; www.getm.eu) during nine months in 2003 and 2004, has already successfully been validated by means of three automatic stations at the Drogden and Darss Sills and in the Arkona Sea with an agreement that is fairly good representing the strength and occurrence of inflow events. A bulk measure for mixing activity is then introduced, the vertically integrated decay of salinity variance, which is equal to the production of micro-scale salinity variance. This measure identifies the Drogden and Darss Sills as well as the Bornholm Channel as mixing hot spots. Further regions of strong mixing are the dense bottom current pathways from these sills into the Arkona Sea, areas around Kriegers Flak (a shoal in the western Arkona Sea) and northwest of the island of Rügen.

Possible effects of dilution caused by offshore wind farms

The research project QuantAS-Off (www.io-warnemuende.de/quantas) is funded by the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU). Researchers at the Baltic Sea Research Institute and the Universities of Rostock and Hannover are considering the possibility of whether offshore-constructions in the area between Kattegat and the western Baltic Sea obstruct the flux of dense and oxygen-rich bottom currents to the Baltic Sea. The main focus of research was the possibility of impacts caused by offshore wind farms. Effects caused by bridge constructions like the one crossing over the Big Belt have also been investigated. Dilution effects through construction-caused turbulent mixing of bottom currents are to be explored. These can produce verifiable impacts on the whole ecosystem of the Baltic Sea. This article shows the problem, the scientific approach and first analysis of natural turbulent mixing on the basis of high-resolution numerical modelling. Concluding results about hydrodynamic impacts caused by wind farms will be available by 2009.

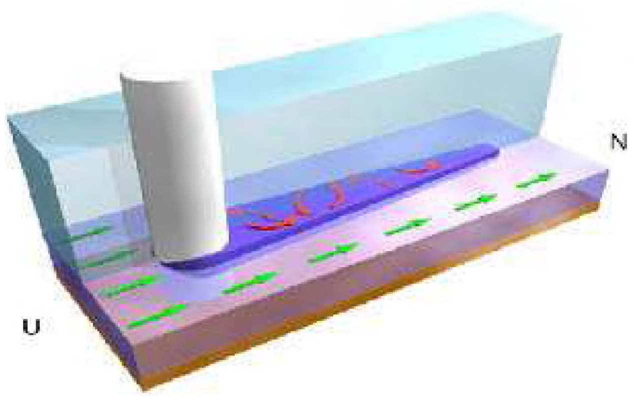

Figure 1: Draft of the effect of an in the bottom of the sea anchored cylinder to a layered current. Green arrows show a directed current of dense bottom water, red arrows show the Kármán vortex street that is generated by the cylinder. (Diagram by Jan Donath, Baltic Sea Research Institute)

Because of the limited number of locations onshore, and the superior wind conditions offshore, offshore wind farms are being planned in the North and Baltic Seas. While the currents in the coastal areas of the North Sea produce a vertical mixing of the water column, the water mass of the Baltic Sea is typically characterised by strong stratification. This stratification is based on differences of salinity caused by fresh water supply from rivers (e.g. the Rivers Oder, Weichsel and Neva), and by saltwater inflows from the North Sea, which flow from Skagerak and Kattegat, over the Danish belts and the Sound into the Arkona Sea. The heavy saline North Sea water shifts under the discharge of the less saline and therefore lighter water from the Baltic Sea. As soon as the inflowing North Sea water reaches the shallow sills of the Öresund (only 7 m Drogden Sill), and the sill between the Darss and the Danish island Falster (20 m Darss Sill), it descends and flows along the bottom of Arkona Sea, propelled by the slope of the soil, slowed by bottom friction, and diverted to the right by the rotation of earth. On its way through the Arkona Sea, the saline water current dilutes due to the turbulent mixing with less saline surface water (see idealised model simulation fig. 4). Then it flows over the Bornholmsglatt between the Danish island of Bornholm and the Swedish coast, and into the Bornholm Basin. There the diluted North Sea water is stratified in depths between 60 and 80 m. The water located underneath is heavier, while the water lying above is lighter.

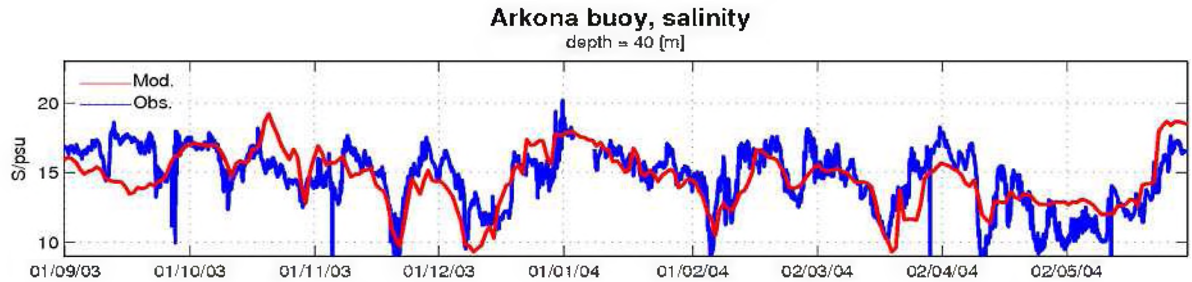

Figure 2: Validation of the model (BURCHARD et al. 2007) shows consistency between the station measurements and the results of the model. The comparison between simulated and measured salinity in a depth of 40 m in the Arkona Sea can be seen here.

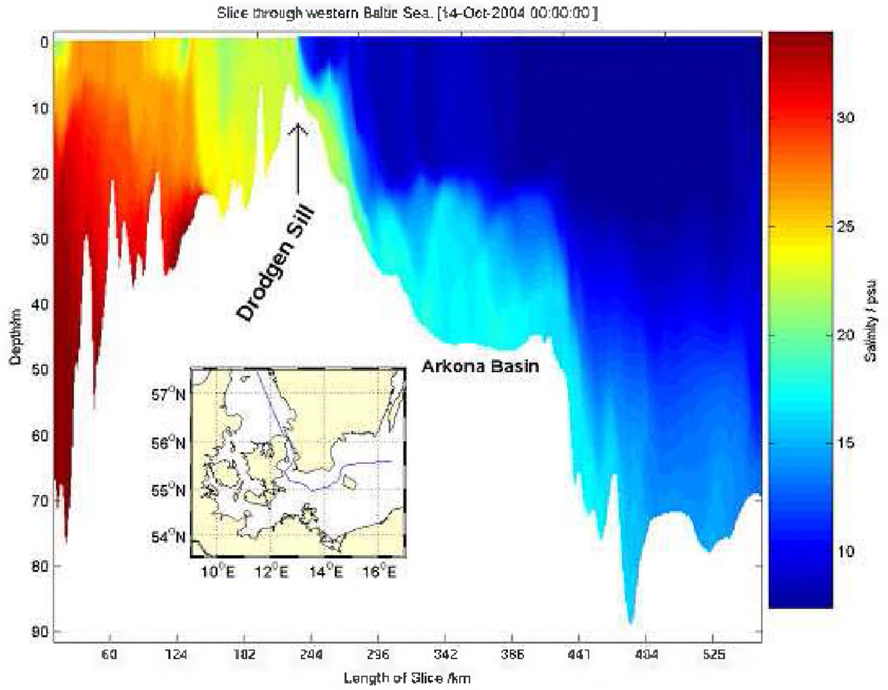

Figure 3: Diagram of a horizontal section through the western Baltic Sea from Kattegat to Bornholm Basin. The strong vertical stratification in the area of the Baltic Sea can be seen here as well as the relevance of the very shallow Drodgen Sill as one of the last barriers for the inflow of dense saline North Sea water into the Baltic Sea. An inflow that suddenly passes over the Drodgen Sill on its way to the Arkona Basin is also shown.

Ecological consequences of additional turbulent mixing

What ecological relevance does the layering in the Bornholm Basin have? Dead organic material descends after a massive increase of phytoplankton and zooplankton (algan bloom) and decays on its way to the bottom. This is a process in which in water dissolved oxygen is dissipated. The oxygenation of oxygen rich surface water is severely limited by the stable saline stratification, so that an oxygen deficiency quickly develops in depths under 60 m.

This can cause a hazard to the development of cod spawn that normally floats at these depths. The only possibility of oxygenating depths below 60m is the inflow of saline water from the North Sea, which contains especially high amounts of oxygen in the winter. These inflows of saline water denote a lifeline for the Bornholm Sea. The stronger the dilution of the North Sea water on its way through Arkona Sea, the lighter the water becomes, and the shallower it can be layered into the stable layered Bornholm Basin, leading to the effect that with strong dilution a greater area of the Bornholm Basin will not be oxygenated. The two described events are natural processes, apart from the amplification of the algal bloom that is caused by over-fertilisation of the sea due to agriculture, and the increased attrition of oxygen in deeper layers of Bornholm Basin.

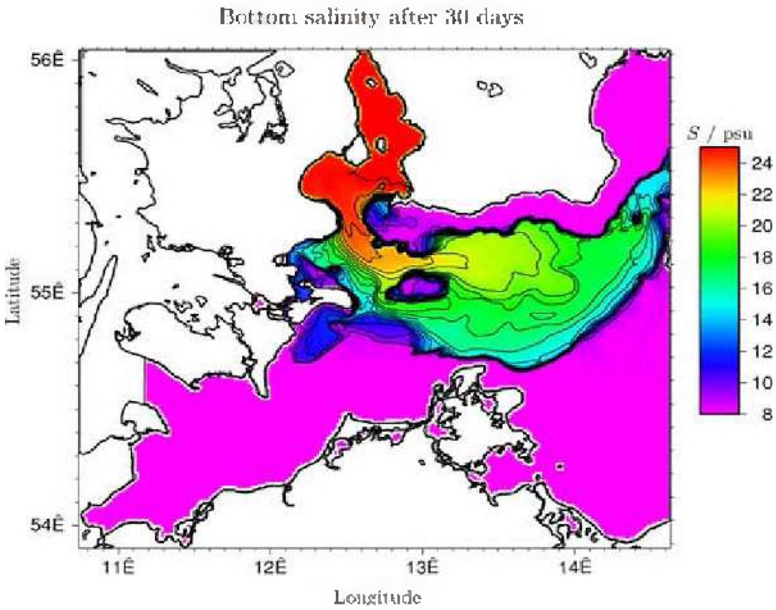

Figure 4: Bottom salinity in an idealized numerical simulation in the area of the Arkona Sea (BURCHARD et al. 2005).

Understanding natural turbulent mixing

The question now is whether the construction of offshore wind farms in the area of the Arkona Sea will intensify the natural dilution of the North Sea water, and whether it can negatively influence the supply of oxygen in the Bornholm Basin. To be able to answer this question with certainty, the natural turbulent mixing and the process of dilution have to be understood in a better way. The influence of offshore wind energy plant's fundaments must also be further investigated. Since the beginning of 2005 this problem has been approached in two research projects that are coordinated by the Baltic Sea Research Institute Warnemünde (IOW). The so-called QuantAS-Projects (Quantification of water mass transformations in the Arkona Sea) have investigated the natural turbulent mixing (QuantAS-Nat) and the turbulent mixing due to offshore wind farms (QuantAS-Off) in the Arkona Sea. To the QuantAs consortium belong German, Polish, Swedish and Danish marine scientists. The currents of saline water through the Arkona Sea were surveyed with different measuring instruments during five QuantAS cruises. German marine research ships and a polish research ship took part on the cruises. One discovered that the main current running through the Sound turns to the east after passing over the Drogde Sill. Then it flows along the northern edge of the Kriegers Flak shoal into the wide Arkona Basin. Surprisingly high current speeds of up to 1 m/s (3.6 km/h) were measured. The current of saline water had a thickness of up to 10 m, while it was up to 10 kg/m^3 denser than the surface water lying above. Idealized (fig. 4) and actual (fig. 3) computer simulations of the whole area of Kattegat through the Arkona Sea up through the Bornholm Basin made by IOW were able to simulate the whole entrainment of saline water, which helped to understand its dynamics in a better way.

The possible impact caused by a cylindrical anchorage of a wind energy plant at the bottom of the sea is shown in fig. 1. The surface water is widely calm while dense bottom currents stream against the cylinder. In lee of the cylinder a Kármán vortex pathway causes turbulences and internal waves. It also can determine a turbulent mixing with dilution of the bottom currents at further distances.

Project partners of the University Hanover and the University Rostock have investigated how the fundaments of wind energy plants affect the currents. The colleagues in Rostock from the Institute of Maritime Systems and Fluid Engineering (under the supervision of Prof. Dr. Alfred Leder) constructed a flow channel. In this channel the saline water currents flow around a cylindrical fundament in a full scale of 1:100. The colleagues from Hanover (under the supervision of Prof. Mark Markofsky) developed high-resolution computer simulations of the layered flow around the cylinder.

In a comparison of both methods, it should be investigated how a fundament could have an effect on the current. Then it could be derived how a wind farm (consisting of 80 individual wind energy plants) changes the current. The mixing effect of one or more wind farms will then be integrated in the computer model of the Arkona Sea by IOW. The impacts to the current caused by wind farms can then be calculated.

The first general conclusions on the potential of turbulent mixing caused by wind farms in the Arkona Sea can already be made. Wind energy plants constructed at depths shallower than 25 m barely obstruct the influx of saline water. The currents of saline water flow along the valley through the Arkona Basin that is located beneath that depth. The planned wind farms (Kriegers Flak and Adlergrund) might be constructed at depths reaching from 20 m to 40 m. Some of the fundaments could extend into the currents of saline water. However their number is so marginal that an additional detectable dilution is unlikely. The planned wind farms are located slightly set apart from the most important saline water current, which flows north of Kriegers Flak (see also the animation of the bottom salinity: www.getm.eu/docs/quantas_off_bottsal.avi). Wind farms are also planned in Polish, Swedish and Danish waters, so that all planned wind farms together could cause an additional detectable dilution of the inflowing North Sea current. One of the tasks of IOW and its QuantAS-Projects is to give recommendations for the location of offshore wind farms, and to show capacity limits for the construction of offshore wind farms in the whole Arkona Sea.

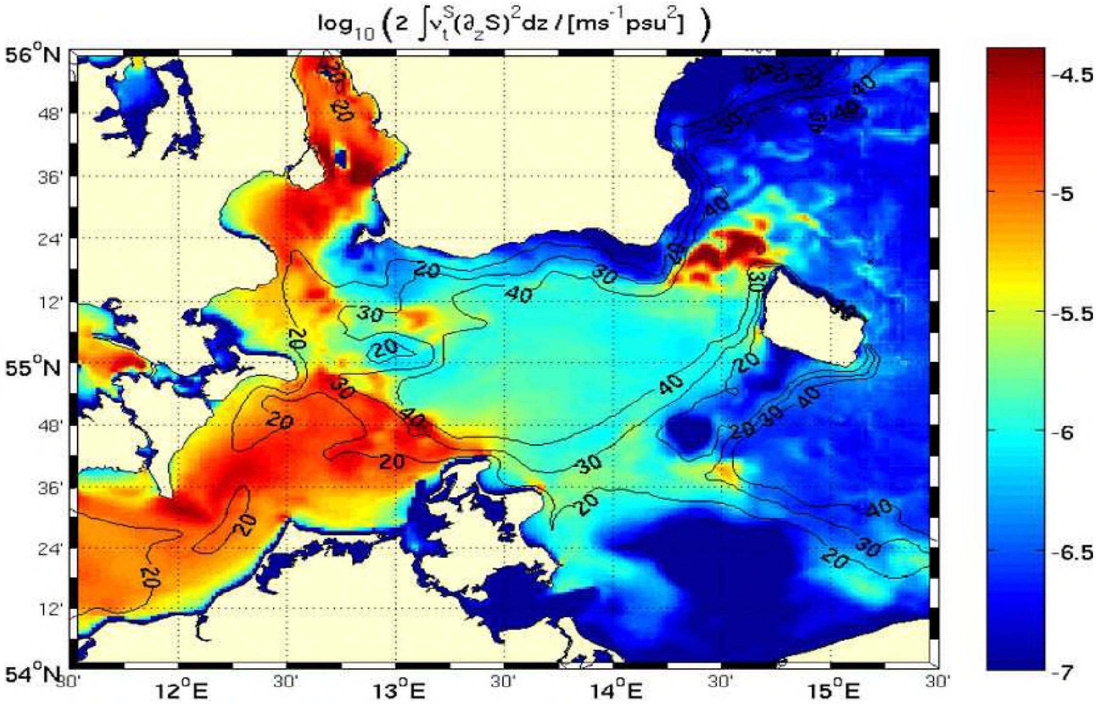

Figure 5: This diagram shows the intensity of natural turbulent mixing in the western Baltic Sea with high-resolution numerical simulations by the Baltic Sea Research Institute (BURCHARD et al. 2007).

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Project - IMKONOS - Generation of preconditions for an interdisciplinary network of competence on marine research

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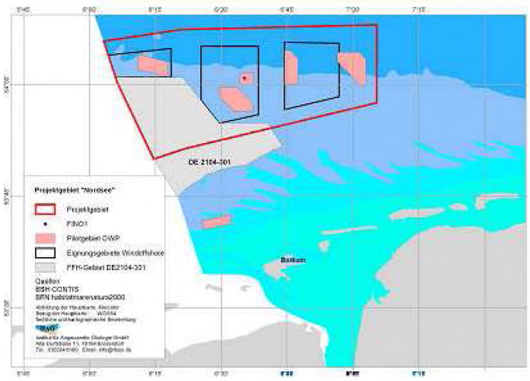
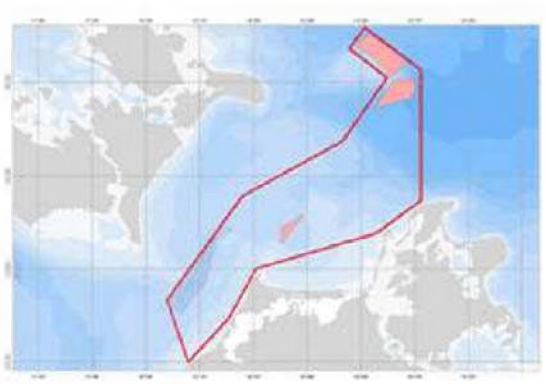
The „interdisciplinary network on marine research for the North and Baltic Seas (IMKONOS)“ has the objective to characterise the biotic and abiotic marine environment in selected model areas. The existing data of members of the network (i. a. Baltic Sea Research Institute - IOW) are to be used.



Model area North Sea



Model area Baltic Sea

Figure 1: Model areas in the project IMKONOS

The project IMKONOS (BMU, Fo. 0327597) should be understood as a feasibility study. In order to merge data in a methodologically convenient way for an aimed characterisation of the area, it must be determined which information from existing data can be used. On the other hand, an information-technical concept should be developed at the same time, so that the practical establishment of an adequate information portal is made possible.

It is not planned to change the data preservation, the data administration or the structure of data of the different members of the network. Rather, methods should be developed and implemented which allow the members to assess information from their data, to investigate, and if applicable to make them available for IMKONOS. The IMKONOS ensures that all the information is geographically, temporally and methodologically adequate. Furthermore, an information portal will be developed that allows the user to set the actual standard of knowledge for the characterisation of biotic and abiotic marine environments, at first in selected model areas.

IMKONOS can be technically classified as „data mining“, which means that it develops a spectrum of methods for the extraction of information from more or less structured data in different technical realizations, and that it evaluates data with regard to a defined objective function.

The advantages of this procedure are obvious. Tasks will be solved by IMKONOS that every holder of data normally has to manage, e.g. the transfer of data to other parties, the implementation of statistic methods, the development of classifications up to the graphical presentation (histograms, time series, legends) or the selection and storage of maps and pictures (aerial images, satellite images). Another advantage for the data holder is the standardised data inquiry. The supply of a tool for data inquiry, data control and conversion in an XML-structure is a substantial component of the project. This tool will be developed within a „prototyping“ context and will be available for the data holder. The data is documented and will be provided in a commonly consistent form. Through the methodological, temporal and geographical merging of information, further complex area-analytical methods can be developed and implemented. This integrates methods for the calculation of iso-lines and iso-areas as well as common voting systems, e.g. clustering and filter techniques. These methods will be developed for the information portal and will be available for every member.

The approach for IMKONOS is temporally and methodologically structured in phases. The current Phase 1 has the objective of requesting every member of the network to supply model data, to develop a kind of „prototyping“ in which explorative methods in consultation with ecologists may be developed as well as techniques for the exchange of data, as mentioned above. As long as the overview of the available data and solutions is not available, the „prototyping“ only confines itself to the available stock by the single member. The synopsis (phase 2) of the individual results will later afford the development of great synergetic effects, which will require a revision of the prototype solutions.

The procedure is made clear by illustrating the example of the first prototype by IOW, working group of Prof. Burchard: Modelling of Flow and Transport. The working objective of Professor Burchard at IOW is the closed modelling of flow and transport processes via a three-dimensional HN-model in the western and central Baltic Sea over a period of five years. As a result of these calculations, a volume of data will be produced that will probably lie in the terra byte size range and will not be directly usable for the operators. The ecologist is neither interested in every single dataset nor in each calculated dimension. However, it is essential for his work to be able to access information with regional references e.g. salinity and temperature of the water. For the „prototyping“, every calculation layer of the model and the dimensions of water temperature and salinity have been chosen in a time pattern of 12 hours. For the bottom layer the shearing stress, for the surface layer the water level and for all the other layers the vertical impulse exchange (as a dimension of turbulence) and the flow vectors are added. For the first step, the dataset of the "prototyping" was limited to one month, February 2002.

In the „prototyping“, statistical methods for the analysis of time series have been implemented and have been used for the time series of every single part of the grid of the model and for every parameter of calculation. A method for transformation between coordinate systems allows one to choose one of the available maps and to show the statistical parameters. The presentation in an internet browser is based on an automatic classification of the values through statistical characteristics and provides each with a coloured legend. It is essential to first compile an image of the area for the development of a characteristic of an area. This will be supported as follows. On the one hand a film of stock data can be calculated for the operator and can be observed, especially for a first evaluation of the dynamics of the flow this already can generate hints for the procedure to choose. On the other hand the collateral results of the statistical analysis for every part of the grid can be directly accessed and seen in the map (diagram of time series, histogram, general descriptive statistics: quantiles, minimum, maximum, medium, dispersion, median).

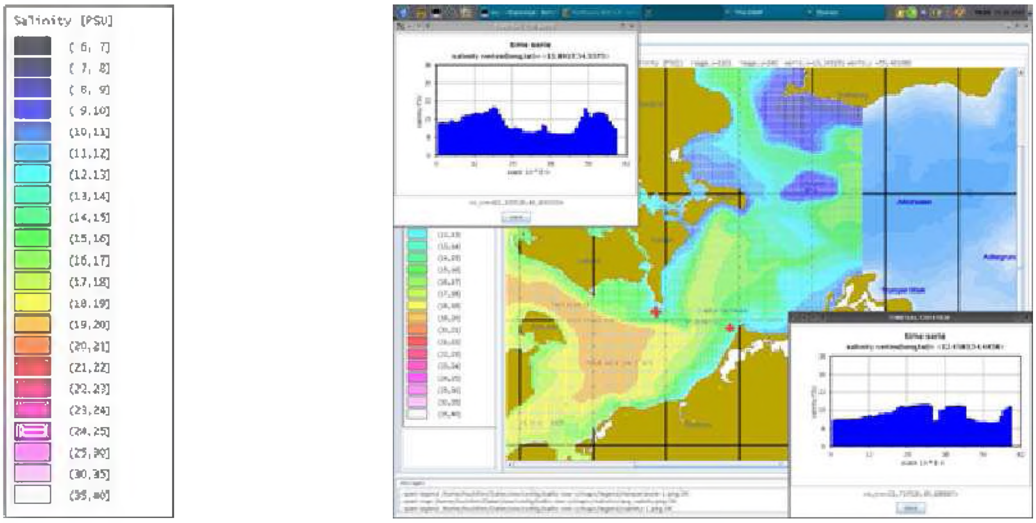


Figure 2: Median of salinity of the bottom layer, the insets show the dynamic of one month of the with a red cross marked cells (2 measurements [events] per day)

The next step would be the development of voting methods. For example isoline-maps of the exceeding frequency of shearing stress (How many hours a year the shearing stress exceeds a grid cell with the value of 1.5 N/m^2?) could be layered / merged with the dispersion of sediments. Generally spoken special characteristics of parameter classifications, can be e.g. geographically assigned via cluster analysis and be used for chosen investigation areas.

The method and techniques for visualisation should be returned to each member of the network, the IOW, and should be used there. The mostly elegant way to do so is through the use of XML-structures. Different information can be packed and transported in these structures. The available prototype („Ostsee.xml") contains e.g. information about authorship, about the settings of the model, the statistical methods of analysis and classification, the used projection, maps and coloured legends.

Similar to the exchange of results, the exploration and the conversion of data from the system of IOW into the IMKONOS-System are also steered by an XML-file.

Finally, it should be pointed out that according to the actual knowledge in excess of the prototype no raw data will be delivered, yet those data should remain where they are and where they are administered. As a the result of the „prototyping", some information that emerges as convenient for the purpose of characterising maritime habitats will be introduced in the feasibility study. This information can be processed by members of IMKONOS, or with instruction from us. The developed solutions for the extraction, preparation and visualization of information are filed transparently in XML, so that they can be controlled, checked and used by every professional without any additives. If a consensus for this were to be established, all members of IMKONOS could publish their results with the same models of classification and colour. This would already establish better collaboration.

Work on this supported research project began at the end of last year. The possibility of collaboration exists for interested parties.

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Summary of the panel discussion

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Panel Participants:

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The two-day event finished with a panel discussion. The panel participants included representatives of governmental authorities, carriers, scientific and environmental organisations. The central question of the discussion was focused on the earlier presentations about the comprehensive research activities that were funded by the German Ministry for the Environment within the accompanying ecological research. Thus the question was asked which conclusions from the actual research results could be considered in order to expedite the use of offshore wind energy.

Each of the discussion participants first had the chance to give an initial statement, then the panel and the audience discussed these statements.

Basically, the panel agreed that the use of offshore wind energy must be established in order to support climate protection and the gradual elimination of nuclear power. A timely implementation, as the strategy of the Federal Government for the use of offshore wind energy had intended, was delayed. The time was, however, used for important research activities that dealt with fundamental investigations of marine environments as well as the potential effects on the marine environment as caused by offshore wind energy use. The research results offered advice on an ecologically compatible and responsible expansion of offshore wind energy. Further research is now necessary with regard to the actual use of offshore wind energy and the tangible effects on the marine environment. Activities regarding the research on effects shall be addressed at the future test site, the offshore wind farm Alpha Ventus. Prognoses claimed in proposal documents could therefore be confirmed against real effects of offshore wind energy turbines on the marine environment, while further open questions regarding the impacts on marine organisms may be answered.

It is to be taken into consideration, that the research activities in this single monitoring on this wind farm to be realised cannot be assignable of necessity. Therefore extensive surveys should not be neglected. Especially these can fill knowledge gaps about cumulative effects.

For the overall process of realization of offshore wind energy in the EEZ, it was pointed out that although a number of licences are given, a spatial planning for the does not yet exist. The whole approval process was evaluated as very complicated, as so many licenses must be obtained from the federal government and federal coastal states for the realization of just one wind farm.

As to the final question about which further research activities will be necessary within the next five years from the point of view of the panel participants, the following points were emphasized.

Basically a stronger international collaboration for the exchange of experiences in regard to the use of offshore wind energy is needed. Research co-operations already exist with Denmark and France and research cooperation with Sweden is currently in negotiation.

In addition the already existing and the future research results should be connected with each other in a way that enables all participants of the approval process to give clear evaluations and to make the approval process clearer and faster.

With regard to bird migration and collision risk, an enhanced collaboration of the ongoing and completed research projects is needed in order to develop strategies to minimize collision risks.

In principle, the realization of the first wind farm projects was seen as necessary for the realization of further improvement, development and optimisation challenges.

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